

Technical Support Document

for

**EVALUATION OF THE CALIFORNIA ENHANCED VEHICLE
INSPECTION AND MAINTENANCE (SMOG CHECK) PROGRAM
April 2004 Draft Report to the Inspection and Maintenance
Review Committee**

June 2004

Estimates of emissions benefits in the *Evaluation of the California Enhanced Vehicle Inspection and Maintenance (Smog Check) Program (April 2004)* were calculated by the Air Resources Board (ARB) and the Bureau of Automotive Repair (BAR). Additional technical analyses were conducted independently by Sierra Research.

This document provides details of the methodologies and calculations used in the evaluation. Part 1 explains the analyses conducted by ARB staff, and Part 2 explains further analyses conducted by Sierra Research.

California Enhanced Inspection and Maintenance (I/M) Program Evaluation

TECHNICAL SUPPORT DOCUMENT

PART 1

This portion of the Technical Support Document (TSD) describes the approaches and methods that the Air Resources Board (ARB) used to calculate the emission benefits and cost effectiveness for the draft *Evaluation of the California Enhanced Vehicle Inspection and Maintenance (Smog Check) Program (April 2004)*. The final TSD will reflect any revisions in the final evaluation report. Methodologies are explained in each of the following chapters:

- 1.1 Total Statewide I/M Benefits for 2002
- 1.2 Enhanced I/M Benefits for 2002, 2005, and 2010
- 1.3 Cost Effectiveness of Smog Check in Enhanced Areas in 2002
- 1.4 Emission Benefits of Changing the 30-year Rolling Exemption
- 1.5 Cost Effectiveness of Changing the 30-year Rolling Exemption
- 1.6 Emission Benefits of Annual Inspection of Vehicles Over 15 Years Old
- 1.7 Cost Effectiveness of Annual Inspection of Vehicles Over 15 Years Old
- 1.8 Emission Benefits of Annual Inspection of Taxicabs
- 1.9 Cost Effectiveness of Annual Inspection of Taxicabs

Background. ARB staff used the EMFAC2002 emissions model to estimate the emission benefits presented in this document. EMFAC is a sophisticated mathematical model and computer program that divides on-road vehicles into thirteen classes including passenger cars, light- and heavy-duty trucks, buses, motor homes, and motorcycles. EMFAC can create an inventory for any calendar year from 1970 to 2040; each calendar year includes up to 45 vehicle model years. EMFAC includes vehicles that use gasoline, diesel fuel, and electricity as fuel sources. The model includes three exhaust processes (vehicle starts, running exhaust, and idling exhaust) and four evaporative processes (diurnal, hot soak, running losses, and resting losses).

EMFAC estimates emissions by multiplying a process rate, usually either grams per hour or grams per mile, by the number of vehicles or other unit of activity (such as vehicle miles of travel). EMFAC then expresses the product as tons per day (tpd) of emissions. EMFAC emission factors are derived from emissions test data for thousands of vehicles of varying ages and types. Emissions tests are conducted by ARB and the United States Environmental Protection Agency (U.S. EPA). Estimates of vehicle population in EMFAC are derived from Department of Motor Vehicles (DMV) registration data. Activity data (vehicle miles of travel (VMT) at various speeds) are typically obtained from local transportation planning agencies, such as councils of governments or metropolitan planning organizations. Other sources of input data are the California Department of Transportation, the Bureau of Automotive Repair (BAR), and instrumented vehicle surveys conducted by ARB and U.S. EPA.

The emission factors used in EMFAC are subject to a number of correction factors that adjust the base inventory to more accurately reflect emissions from real-world driving

conditions. These adjustments accommodate a wide range of vehicle speeds, varying ambient air temperatures, varying fuel composition, use of air conditioning, varying soak time between starts, relative humidity, and altitude. The EMFAC model also includes the impact of deterioration on vehicle emissions control systems as the vehicles age.

The EMFAC model includes the impact of the Smog Check vehicle inspection and maintenance program on emissions. EMFAC includes the impacts of each Smog Check program implemented, beginning with the first statewide biennial program introduced in 1984, and continuing through the basic BAR90 and enhanced I/M programs. EMFAC estimates the emissions impacts of the Smog Check program by modeling identification rate (the fraction of vehicles that fail their Smog Check inspections), repair effectiveness (how well failing vehicles are repaired), and vehicle deterioration (how emission rates of vehicles increase over time as they age). These factors are based on data collected in special inspection and maintenance test programs conducted by ARB. Model output is verified by comparison with roadside inspection data collected by BAR and ARB. Also reflected are changes in vehicle population and VMT by vehicle type that occur over time, and changes in emissions due to changes in emissions standards. Documentation for the EMFAC model is available online at <http://www.arb.ca.gov/msei/msei.htm>.

In this document, ARB staff has provided estimates for hydrocarbons (HC) or reactive organic gases (ROG), oxides of nitrogen (NO_x), and carbon monoxide (CO) in tpd for various Smog Check program scenarios. To allow the reader to duplicate calculations, ARB staff provided emission estimates to the nearest 0.01 tpd in all preliminary calculations shown in this report. However, for each emission estimate calculation in the Joint Report to the Legislature, ARB staff carried all the decimal places and rounded the final number to appropriately reflect the actual precision of the calculations. Consequently, some numbers may not appear to add correctly due to rounding.

1.1 Total Statewide I/M Benefits for 2002 (Basic + Enhanced)

ARB staff used EMFAC2002 version 2.2, which was released April 23, 2003, to estimate the emission benefits of the Smog Check I/M program for the basic and enhanced I/M program areas for the 2002 summer season. To estimate the benefits of the statewide I/M program, ARB staff did the following:

1. Estimated the total fleet emissions of the default enhanced I/M program by running the model with the default enhanced I/M program in place.
2. Estimated the total fleet emissions of the basic BAR90 I/M program in the enhanced areas by turning off the enhanced I/M program so that only the basic BAR90 I/M program was in effect.
3. Subtracted the default enhanced I/M program emissions from the basic BAR90 I/M program emissions to determine the benefits of the default enhanced I/M program (See Table 1.1.1).

4. Calculated an off-model adjustment¹ to estimate benefits from an increase in the number of vehicles directed to test-only stations in 2002 not reflected in the default enhanced I/M program in EMFAC2002 (See Table 1.1.2).
5. Estimated the benefits of the basic BAR90 I/M program (See Table 1.1.3).
6. Calculated the benefits of the Evaporative System Test improvements (See Table 1.1.4).
7. Summed the total benefits from the enhanced I/M program (with off-model adjustments), the basic BAR90 I/M program, and the Evaporative System Test improvements (See Table 1.1.5).

Table 1.1.1 summarizes the results from the EMFAC2002 model runs to estimate the benefits of the default enhanced I/M program in EMFAC2002. The current basic BAR90 I/M program fleet emissions summarized in Table 1.1.1 included the added benefits of fuel cap testing and liquid leak checks.

Table 1.1.1

Statewide Enhanced I/M Benefits (default) Calendar Year 2002 Summer Season TPD			
	HC	NOx	CO
Total Fleet Emissions-Current Basic BAR90 I/M Program	914.63	1688.07	9357.05
Total Fleet Emissions-Default Enhanced I/M Program	864.50	1614.98	8713.82
Default Enhanced I/M Program Benefit	50.13	73.09	643.23

More Vehicles to Test-only Stations. The default enhanced I/M program in the model assumes that 15% of vehicles are directed to test-only stations. By the end of 2002, BAR was directing 36% of the vehicles to test-only stations. To be conservative, ARB staff assumed that the number of vehicles being directed to test-only in summer 2002 was approximately 20%. ARB staff adjusted the emissions modeled by EMFAC2002 to reflect the additional vehicles being directed to the enhanced I/M program.

ARB staff estimated the ROG, NOx, and CO benefits from increasing the percentage of vehicles directed to test-only by calculating the overall failure rates for 15% and 20% directed. Based on data from the BAR Executive Summary report for 3rd quarter 2002, test/repair stations have a failure rate of 9.9%. Based on data ARB staff received from BAR on December 16, 2002, the failure rate for vehicles randomly directed to test-only stations was 25.1% for fiscal year 2001/2002². ARB staff used the failure rate for the randomly directed vehicles to avoid overestimation of benefits from use of the higher failure rate for the more-polluting "High Emitter Profile" vehicles. The emissions benefits

¹ Off-model adjustments are needed to account for certain program elements not included in the default Smog Check programs modeled in EMFAC2002.

² The difference in failure rates could result from several factors, including test/repair stations conducting pre-inspection repairs to reduce chances of failure prior to the officially recorded smog check inspections. Relative failure rates will be re-examined with more recent data prior to release of the final evaluation report.

were assumed to be proportional to the increase in the expected failure rate of going from 15% to 20% directed.

To calculate the expected increase in failure rate, ARB staff calculated the overall failure rate for 15% direction, 20% direction, and the fractional increase in benefits as shown below. ARB staff assumed that vehicles not directed to test-only would be tested at test/repair stations.

$$\begin{aligned} \text{Overall failure rate for 15\% directed} &= (9.9)(.85) + (25.1)(.15) = 12.18 \\ \text{Overall failure rate for 20\% directed} &= (9.9)(.80) + (25.1)(.20) = 12.94 \\ \text{Fractional increase} &= (12.94 - 12.18)/12.18 = 0.0624 \end{aligned}$$

The failure rate fractional increase is then multiplied by the emission benefit associated with the enhanced I/M program. Table 1.1.2 displays the additional benefits due to the increase in test-only direction from 15% to 20%.

Table 1.1.2

Enhanced I/M Program Area Off-Model Adjustment Additional benefits for 15 to 20% direction to Test-Only Stations Calendar Year 2002 Summer Season TPD			
	HC	NOx	CO
South Coast Air Basin	1.25	1.74	16.09
Coachella Valley	0.04	0.06	0.59
Ventura County	0.05	0.07	0.65
Antelope Valley Air District	0.03	0.04	0.38
San Joaquin Valley Air Basin	0.33	0.53	4.64
Sacramento Region	0.21	0.30	2.81
San Diego County	0.29	0.44	3.52
Total Additional Benefit for Directing More Vehicles to Test-Only Stations	2.20	3.20	28.67

Basic Program Benefits. ARB staff used the EMFAC2002 model version 2.2 to estimate statewide emission benefits of the basic BAR90 I/M program. ARB staff ran the EMFAC2002 model using the no I/M assumption to determine the fleet emissions as if the State had no I/M program. ARB staff then ran the EMFAC2002 with the default basic BAR90 I/M program. Table 1.1.3 shows the results from these analyses, including the basic BAR90 I/M program statewide emission benefits.

Table 1.1.3

Statewide Basic BAR90 I/M Program Benefits Calendar Year 2002 Summer Season TPD				
	HC Exhaust	HC Evap	NOx	CO
Total Fleet Emissions-No I/M Program	635.15	437.99	1769.46	10045.57
Total Fleet Emissions-Basic BAR90	560.23	437.98	1688.07	9357.05
Basic BAR90 I/M Program Emission Benefit	74.92	0.01	81.39	688.52

Evaporative Improvements. BAR implemented some enhanced I/M program improvements statewide instead of in enhanced areas only, including gas cap inspections for evaporative emission leaks and liquid fuel leak testing. Therefore, to determine the emission benefits, ARB staff ran the EMFAC2002 model version 2.2 for the basic BAR90 I/M program statewide with the evaporative emission system improvement option. Table 1.1.4 summarizes the net effects of the evaporative emission system improvements.

Table 1.1.4

Statewide Evaporative System Benefits Calendar Year 2002 Summer Season TPD				
	HC Exhaust	HC Evap	NOx	CO
Total Fleet Emissions: Basic BAR90 I/M Program	560.23	437.98	1688.07	9357.05
Total Fleet Emissions: Basic Including Statewide Evap System Improvements	560.23	354.40	1688.07	9357.05
Evaporative Test Improvement Benefit	0	83.58	0	0

Summation of Current Program Benefits. Table 1.1.5 sums the emission benefits from the basic BAR90 I/M program, the statewide evaporative test improvements, the EMFAC2002 default enhanced I/M program, and the off-model adjustment for the increase of vehicles sent to test-only, to total the statewide benefits of the Smog Check program.

Table 1.1.5

Total Statewide Emissions Benefits Calendar Year 2002 Summer Season TPD					
	Exhaust HC	Evap HC	Total HC	NOx	CO
Basic BAR90 I/M Program Emission Benefit	74.92	0.01	74.93	81.39	688.52
Evaporative Test Improvement Benefit	0	83.58	83.58	0	0
Default Enhanced I/M Program Benefit	50.13	0	50.13	73.09	643.23
Total Additional Benefit for Directing More Vehicles to Test-Only Stations	2.20	0	2.20	3.20	28.67
Total Statewide Smog Check Benefits	127.25	83.59	210.84	157.68	1360.42

1.2 Enhanced I/M Benefits for 2002, 2005, 2010

ARB staff used EMFAC2002 version 2.2 (released April 23, 2003) to analyze the emission benefits of the enhanced I/M program for the 2002, 2005, and 2010 summer seasons. To estimate the emission benefits of the enhanced area I/M program, ARB staff did the following:

1. Estimated the emission benefits of the basic BAR90 I/M program element in the enhanced I/M areas.
2. Estimated the emission benefits of the default enhanced I/M program element in the I/M enhanced areas.
3. Estimated the emission benefits of program elements in effect not included in the EMFAC2002 default enhanced I/M program.
4. Summed the applicable benefits for each calendar year.

Enhanced Area I/M Benefits in 2002. Based on information provided by BAR, 65% of the statewide vehicle population in 2002 was in enhanced I/M areas. ARB staff multiplied by 0.65 the basic BAR90 I/M program and statewide evaporative test improvement emission benefits previously calculated in Table 1.1.5 to determine the basic BAR90 I/M program benefit in the enhanced I/M program areas. ARB staff used the EMFAC2002 default enhanced I/M program and the test-only increase off-model adjustment from Table 1.1.5 for the remainder of the emission benefits. Table 1.2.1 summarizes the enhanced area I/M program benefits.

Table 1.2.1

Enhanced Area I/M Program Emission Benefits Calendar Year 2002 Summer Season TPD			
Enhanced Area Benefits	HC	NOx	CO
Benefits from Basic BAR90 I/M Requirements	48.70	52.90	447.54
Benefits from Evap Test Improvements	54.33	0	0
Benefits from Enhanced I/M Requirements (default + test-only)	52.33	76.29	671.90
Total Emission Benefit in Enhanced Areas	155.36	129.19	1119.44

Enhanced Area I/M Benefits in 2005 and 2010. For 2005 and 2010, ARB staff quantified the HC and NOx emission benefits of the basic BAR90 I/M program, the implemented Evaporative Test Improvements (gas cap testing and liquid leak check), and the default enhanced I/M program. Based on information provided by BAR, 87% of the statewide vehicle population in 2005 and 2010 will be subject to the enhanced I/M program. Table 1.2.2 displays the emission benefits.

Table 1.2.2

Enhanced Area I/M Program Emission Benefits Without Post 2002 Improvements Calendar Year 2005 and 2010 Summer Season TPD				
Enhanced Area Benefits	2005		2010	
	HC	NOx	HC	NOx
Benefits from Evaporative Test Improvements	75.36	0	64.96	0
Benefits of EMFAC Default Enhanced I/M Beyond Basic BAR90 I/M Program	71.88	114.26	53.66	96.72
Enhanced Emission Benefit Without Post 2002 Improvements	147.24	114.26	118.62	96.72

For 2005 and 2010, ARB staff also quantified the benefits of the improvements to the enhanced I/M program that were implemented or scheduled to be implemented in 2002 or later. Achieving full benefit from a Smog Check Inspection improvement requires that it be in place for at least one full I/M cycle (two years). ARB staff estimated the future benefits for these improvements in calendar years 2005 and 2010. The improvements that have been implemented or committed to implementation during 2002 or later years are:

- Adding areas to enhanced I/M.
- Increasing the percentage of vehicles directed to test-only stations to 36%.
- Loaded mode testing for gasoline trucks between 8,501 and 9,999 lbs. gross vehicle weight rating.
- Low pressure evaporative system testing.

Additional Areas. Table 1.2.3 lists the number of vehicles per air basin added to the I/M program due to new areas added to the enhanced I/M program. BAR provided ARB staff with the number of vehicles shown in Table 1.2.3. These new areas are not currently reflected in the EMFAC2002 model. "Full enhanced" refers to vehicles subject to all elements of the enhanced I/M program, including being directed to test-only stations. "Partial enhanced" refers to vehicles not subject to the test-only provisions.

Table 1.2.3

Summary of New Areas Added to Enhanced I/M Program					
Area (Air District or Air Basin)	Approximate Number of Vehicles Added (estimated May 2002)			Date of Request by Air District	Date of Implementation
	Full Enhanced	Partial Enhanced	Total		
San Joaquin Unified APCD	322,000	519,000	841,000	04/19/01	05/01/02
Ventura County APCD	0	35,000	35,000	06/12/01	07/01/02
Sacramento Metro AQMD	0	33,000	33,000	09/27/01	07/01/02
South Coast AQMD	60,000	243,000	303,000	02/01/02	11/01/02
Placer County APCD	0	58,000	58,000	04/11/02	04/01/03
Yolo-Solano AQMD	38,000	33,000	71,000	12/12/01	04/01/03
San Francisco Bay Area	4,800,000	0	4,800,000	09/27/02	07/01/03- 10/01/03
El Dorado County AQMD	19,000	73,000	92,000	04/16/02	12/01/03

ARB staff estimated the ROG and NOx benefits of these additional areas by first calculating a per-vehicle benefit for the enhanced I/M program as modeled by EMFAC2002 without the added areas. ARB staff calculated the total benefits for the added areas by multiplying the per-vehicle benefits for each county by the number of vehicles being added to enhanced I/M program in that county. The benefits for partial enhanced I/M areas were reduced by 30% to reflect the lower failure rates expected when vehicles go to test-and-repair stations.

For the San Francisco Bay Area, ARB staff assumed that the enhanced I/M program will be fully implemented by January 1, 2004. ARB staff estimated the benefits of enhanced I/M program in the Bay Area by running EMFAC2002 version 2.2, first with the default basic BAR90 I/M program, and then with the addition of an enhanced I/M program implemented on January 1, 2004. The enhanced I/M program that ARB staff modeled is the same as the program currently in place in other areas of the State.

The benefits modeled using EMFAC2002 are based on all vehicles in the Bay Area being included in the enhanced I/M program. In reality, there are several non-urbanized areas within the air basin that will remain in the basic BAR90 I/M program. BAR provided ARB staff with the estimated population split of 98.3% of vehicles in enhanced I/M and 1.7% in basic BAR90 I/M program areas. ARB staff reduced the EMFAC2002-derived benefits by 1.7% to reflect the actual number of vehicles subject to enhanced I/M program in the Bay Area. Table 1.2.4 summarizes the off-model emission benefit adjustment for added areas.

Table 1.2.4

Enhanced Program Area Off-Model Adjustment for Benefits of Added Areas Calendar Year 2005 and 2010 Summer Season TPD				
	2005		2010	
	HC	NOx	HC	NOx
San Joaquin Valley	3.23	5.43	2.32	4.50
Ventura County	.07	.10	.05	.08
Sacramento Region*	.85	1.39	.51	1.08
South Coast	.94	1.50	.54	1.14
Coachella Valley	.08	.13	.05	.09
San Francisco Bay Area	7.51	11.32	9.95	17.3
Total	12.68	19.87	13.42	24.20

*Includes portions of Yolo, Solano, and Placer Counties

More Vehicles to Test-only Stations. ARB staff estimated the ROG and NOx emission benefits for increasing vehicles directed to test-only by calculating the overall failure rates for 15% and 36% directed. Test/repair stations have a 9.9% failure rate based on data from the BAR Executive Summary report for 3rd quarter 2002. Based on data ARB staff received from BAR on December 16, 2002, the failure rate for vehicles randomly directed to test-only stations was 25.1% for fiscal year 2001/2002. ARB staff used the failure rate for the randomly directed vehicles to avoid overestimation of benefits from use of the higher failure rate for the more-polluting "High Emitter Profile" vehicles. The emissions benefits are assumed to be proportional to the increase in the failure rate of going from 15% to 36% directed.

To calculate the proportional increase in failure rate, ARB staff calculated the overall failure rates for 15% direction and 36% direction, then calculated the fractional increase in failure rate as the difference between the two overall failure rates, as shown below.

$$\begin{aligned}
 \text{Overall failure rate for 15\%} &= (9.9)(.85) + (25.1)(.15) = 12.18 \\
 \text{Overall failure rate for 36\%} &= (9.9)(.64) + (25.1)(.36) = 15.37 \\
 \text{Fractional increase} &= (15.37 - 12.18) / 12.18 = 0.262
 \end{aligned}$$

The fractional increase in failure rate was multiplied by the benefit of enhanced I/M over basic BAR90 I/M to estimate the incremental benefit of going from 15% to 36% directed. ARB staff estimated the emission benefit for the South Coast Air Basin (SCAB) for both the 2005 and 2010 calendar years. ARB staff extrapolated the SCAB numbers to all enhanced areas statewide using an estimate that SCAB represents 48.5% of statewide enhanced (provided by BAR). Table 1.2.5 shows the additional benefits from increasing test-only direction from 15% to 36% for both the 2005 and 2010 calendar years.

Table 1.2.5

Enhanced Program Area Off-Model Adjustment Additional Benefits for 15 to 36% Direction to Test-Only Stations Calendar Year 2005 and 2010 Summer Season TPD				
	2005		2010	
	HC	NOx	HC	NOx
South Coast Air Basin	7.6	11.52	5.58	10.01
Remaining Enhanced Areas	8.07	12.23	5.93	10.63
Total	15.67	23.75	11.51	20.64

Heavy-duty Gasoline Trucks. BAR recently implemented loaded-mode testing for heavy-duty gas trucks (HDGT) between 8,501 and 9,999 pounds gross vehicle weight rating (GVWR). ARB staff estimated the benefits by changing the HDGT Smog Check program in the EMFAC2002 model from two-speed idle to acceleration simulation mode (ASM) loaded mode testing and calculated light heavy-duty 1 (LHDT1) benefits as the emission reduction for the LHDT1 vehicle class. EMFAC2002 model LHDT1 ASM benefits are based on light-duty truck ASM benefits. The LHDT1 class in EMFAC2002 includes trucks between 8,501 and 10,000 lb. GVWR. Since the 10,000-lb. trucks will not get loaded mode testing, ARB staff discounted the benefits by 18% to obtain the emission benefits for HDGT. BAR provided ARB staff with 2002 data that shows that 18% of trucks in the 8,501–10,000 lb. class are 10,000 lb. GVWR.

BAR has also informed ARB staff that not all 8,501–9,999 lb. trucks can be loaded-mode tested. In some cases, the physical size of the vehicle will not allow it to fit on a dynamometer, or the drive axle weight exceeds 5,000 lbs. Based on BAR roadside data, about 16% of HDGT cannot be loaded-mode tested. ARB staff reduced the emission benefit estimates by an additional 16% to account for these vehicles.

Using the above method, ARB staff estimated the emission benefit for SCAB for the 2005 and 2010 calendar years. For the 2005 calendar year, ARB staff assumed that HDGT testing would be implemented in 2004. For the 2010 estimate, ARB staff used an implementation date of 2008 to account for the benefits of one full program cycle before the 2010 attainment date for the SCAB. ARB staff extrapolated the SCAB numbers to all enhanced I/M areas statewide using an estimate that SCAB represents 48.5% of statewide enhanced (provided by BAR). Table 1.2.6 shows the emission benefits of HDGT loaded-mode testing.

Table 1.2.6

Enhanced Program Area Off-Model Adjustment Additional Benefit of Heavy-Duty Truck Loaded Mode Testing Calendar Year 2005 and 2010 Summer Season TPD				
	2005		2010	
	HC	NOx	HC	NOx
South Coast Air Basin	.18	.25	.15	.39
Remaining Enhanced Areas	.19	.28	.16	.41
Total	.37	.53	.31	.8

Low-pressure Evaporative Test. MOBILE6 was used to estimate the benefit of low pressure evaporative testing since it is not included in EMFAC2002. The effectiveness of the pressure test as modeled in MOBILE6 is based on the effectiveness for the two states (Arizona and Kentucky) that have successfully implemented the test. MOBILE6 was used to generate evaporative emission factors with gas cap testing only and with gas cap plus pressure testing for the national fleet. ARB staff applied the ratio of evaporative emission factors from the national fleet to the emissions for the I/M fleet in California (vehicles up to 14,000 lb. GVWR) in order to estimate benefits for the pressure test. By using this effectiveness to calculate benefits, ARB staff assumed no more benefit than currently achieved in other states.

ARB staff estimated the emission benefit for SCAB for both the 2005 and 2010 calendar years. ARB staff extrapolated the SCAB numbers to all enhanced I/M areas statewide using an estimate that SCAB represents 48.5% of statewide enhanced (provided by BAR). Table 1.2.7 shows the estimated emission benefits of the low-pressure evaporative test.

Table 1.2.7

Enhanced Program Area Off-Model Adjustment Additional Benefit of the Low Pressure Evaporative Test Calendar Year 2005 and 2010 Summer Season TPD		
	2005	2010
	HC	HC
South Coast Air Basin	1.41	1.12
Remaining Enhanced Areas	1.50	1.18
Total	2.91	2.30

Summation of Post-2002 Improvements. Table 1.2.8 sums the additional benefits of improvements in the enhanced I/M program for post-2002 improvements.

Table 1.2.8

Total Enhanced Program Area Off-Model Adjustment Additional Benefits of Post-2002 Improvements Calendar Year 2005 and 2010 Summer Season TPD				
	2005		2010	
	HC	NOx	HC	NOx
Benefits of Adding Areas to Enhanced I/M Program	12.68	19.87	13.42	24.20
Benefits of 15%-36% Direction to Test-Only Stations	15.67	23.75	11.51	20.64
Benefits of HDGT Loaded Mode Testing	0.37	0.53	0.31	0.80
Benefits of Low Pressure Evaporative Test	2.91	0	2.30	0
Total	31.63	44.15	27.54	45.64

Summation of Benefits. Table 1.2.9 totals the future emission benefits of the enhanced I/M program in California. The total benefit in Table 1.2.9 includes added areas, more vehicles to test-only, loaded mode testing for HDGT and low pressure evaporative test.

Table 1.2.9

Projected Emission Benefits of Enhanced I/M in Future Years Calendar Year 2005 and 2010 Summer Season TPD				
	2005		2010	
	HC	NOx	HC	NOx
Enhanced I/M Post 2002 Improvements	31.63	44.15	27.54	45.64
Enhanced Emission Benefit Without Post-2002 Improvements	147.24	114.26	118.62	96.72
Total Benefit	178.87	158.41	146.16	142.36

Additional Evaporative Benefits. In order to estimate the full impact of the recently implemented Smog Check enhanced I/M improvements, ARB staff added the emission benefit from Table 1.2.8 with Evaporative Test Improvement benefits of the added areas. The added areas Evaporative Test Improvement benefit was incorporated in Table 1.2.2, Benefits from Evaporative Test Improvements.

To estimate the Evaporative Test Improvement benefits for added areas, ARB staff:

1. Multiplied the Evaporative Test Improvement benefits previously estimated in Table 1.2.2 (75.36 tpd HC in 2005 and 64.96 tpd HC in 2010) by the ratio of the statewide enhanced I/M program percentage in 2002 over the statewide enhanced I/M program percentage in 2005 or 2010.
2. Subtracted the above value from the Evaporative Test Improvement benefits previously estimated in Table 1.2.2 (75.36 tpd HC in 2005 and 64.96 tpd HC in 2010).

The 2005 additional benefit = 75.36 tpd HC - 75.36 tpd HC X (0.65/0.87) = 19.06 tpd HC
The 2010 additional benefit = 64.96 tpd HC - 64.96 tpd HC X (0.65/0.87) = 16.43 tpd HC

Table 1.2.10 shows the emission benefits of the recently implemented Smog Check I/M improvements in enhanced I/M areas.

Table 1.2.10

Projected Emission Benefits of Enhanced I/M Improvements in Future Years Calendar Year 2005 and 2010 Summer Season TPD				
	2005		2010	
	HC	NOx	HC	NOx
Enhanced I/M Post 2002 Improvements	31.63	44.15	27.54	45.64
Evaporative Emission Benefits due to Added Enhanced I/M Areas	19.06	0	16.43	0
Total Benefit	50.69	44.15	43.97	45.64

1.3 Cost Effectiveness of Smog Check in Enhanced Areas in 2002

ARB staff estimated the cost effectiveness (CE) of the Smog Check program in enhanced areas in 2002 by determining the total cost of getting a Smog Check and dividing by the emission benefits per I/M cycle. ARB staff assumed the following are included in the cost of getting a Smog Check:

- Smog Check inspection cost for every vehicle.
- Smog Check certification fee for every vehicle.
- Repair costs for vehicles that fail the Smog Check inspection.

The Smog Check certification fee was \$8.25 in 2002. ARB staff obtained the following information from the calendar year 2002 BAR Executive Summary report:

- Average enhanced I/M inspection cost = \$45.83.
- Average enhanced I/M area initial failure rate = 15.6%.
- Average enhanced area repair cost = \$143.18.
- Number of vehicles annually subject to initial tests in enhanced I/M areas = 7,210,771.

ARB staff calculated the total cost of Smog Check per I/M cycle by totaling the cost of all vehicles and the additional cost for vehicles that fail. The cost to inspect and certify all vehicles equaled the total number of vehicles for two years multiplied by the Smog Check inspection cost plus the certification fee:

$$2 \times 7,210,771 \text{ vehicles} \times (\$8.25 + \$45.83)/\text{vehicle} = \$779,916,991$$

The additional cost for failing vehicles equaled the failure rate multiplied by the number of vehicles for two years multiplied by the repair cost:

$$.156 \times 2 \times 7,210,771 \text{ vehicles} \times \$143.18/\text{vehicle} = \$322,120,716$$

Total cost = \$779,916,991 + \$322,120,716 = \$1,102,037,707

The cost effectiveness equaled the total cost divided by the emission reductions over two years.

CE = \$1,102,037,707 / ((155 tpd ROG + 129 tpd NOx) X 2 X 365)

CE = \$5317/ton

Table 1.3.1

Cost Effectiveness Estimate for Smog Check Program in Enhanced Areas Calendar Year 2002	
Enhanced area initial test failure rate (%)	15.6%
Total average ASM inspection cost - includes \$8.25 certification fee (\$/Test)	\$54.08
Average Enhanced I/M repair cost (\$/Vehicle)	\$143.18
Average test cost per vehicle (\$)	\$76.42
# of vehicles subject to I/M	14,421,542
Total cost per I/M cycle (\$)	\$1,102,037,707
ROG+NOx benefits (tons/ I/M cycle)	207,273
Cost Effectiveness (\$/Ton)	\$5,317/ton

1.4 Emission Benefits of Changing the 30-year Rolling Exemption

ARB staff analyzed two options for changing the 30-year rolling exemption, exempting only pre-1976 model years and exempting only pre-1966 model years. The latter was calculated as an incremental benefit, i.e., the benefit of including 1966-1975 vehicles.

ARB staff used EMFAC2002 version 2.2 (4/23/03) to estimate the 2010 emission benefits of changing the 30-year rolling exemption for the enhanced I/M program area. In order to determine the emission benefits, ARB staff first estimated the change in vehicle population and then the associated emissions change. Since EMFAC2002 includes both basic BAR90 I/M and enhanced I/M program areas, ARB scaled the EMFAC2002 output to reflect just enhanced I/M areas. Based on information provided by BAR, 87% of the statewide vehicle population in 2010 would be subject to enhanced I/M.

To estimate the emission benefits of replacing the 30-year rolling exemption with a pre-1976 exemption, ARB staff:

1. Ran EMFAC2002 for the entire State with the existing 30-year rolling exemption in 2010. In 2010, the existing 30-year rolling exemption would include 1982 to 2006 model-year vehicles in the Smog Check inspection program.³

³ In 2010, model years 2007, 2008, 2009, and 2010 are exempt from and do not receive any benefits from Smog Check. However, they are included in emissions comparisons.

2. Ran EMFAC2002 with the proposed pre-1976 exemption in 2010. In 2010, the pre-1976 exemption would add the 1976-1981 model year vehicles to the Smog Check inspection program.
3. Subtracted pre-1976 exemption emissions from the 30-year rolling emissions.
4. Estimated the Bay Area enhanced I/M emission benefits in 2010 using the same methodology above.
5. Added the Bay Area enhanced I/M emission benefits to the pre-1976 exemption benefits from task 3 above.
6. Multiplied the sum from task 5 by the proportion of the State that is enhanced in 2010.

Default EMFAC2002 assumes basic BAR90 I/M is in place in the Bay Area. Since the enhanced I/M program has been implemented in the Bay Area, ARB staff adjusted the 2010 output from EMFAC2002 to reflect the additional enhanced I/M program benefit less the basic BAR90 I/M benefit in the Bay Area. ARB staff made separate EMFAC2002 runs for the Bay Area to assess the impact of enhanced I/M program on exempt vehicles that are brought back into Smog Check. Table 1.4.1 displays the emission benefits of enhanced I/M in the Bay Area with the pre-1976 exemption and the additional benefit of no exemption. The benefits do not include the benefits from a low pressure evaporative test. BAR provided ARB staff with the assumption that 98.3% of Bay Area vehicles are in the enhanced I/M program in 2010.

Table 1.4.1

Additional Benefits Due to Enhanced I/M in Bay Area Calendar Year 2010 Summer Season TPD				
	Exh HC	Evap HC	Total HC	NOx
Basic with pre-1976 exemption	4.65	3.35	8.00	6.34
Enhanced with pre-1976 exemption	3.67	3.34	7.01	5.50
Pre-1976 benefits for Bay Area	0.98	0.01	0.99	0.84
Additional Enhanced Bay Area Benefits of Pre-1976 Exemption	0.96	0.01	0.97	0.83
Basic with pre-1966 exemption	10.49	7.51	18.00	13.43
Enhanced with pre-1966 exemption	9.20	7.52	16.72	12.31
Pre-1966 exemption benefits for Bay Area	1.29	-0.01	1.28	1.12
Additional Enhanced Bay Area Benefits of Pre-1966 Exemption	1.27	-0.01	1.26	1.10

Table 1.4.2 displays the emission benefits of replacing the 30-year rolling exemption with a pre-1976 exemption.

Table 1.4.2

Benefits of Replacing 30-Year Rolling Exemption with Pre-1976 Model Year Exemption (Retaining Model Years 1976-1981) Calendar Year 2010 Summer Season TPD				
	Exh. HC	Evap HC	Total HC	NOx
Emissions with current 30-year rolling exemption	263.45	242.32	505.77	1001.76
Emissions with pre-1976 exemption	261.62	242.02	503.64	999.11
Statewide benefits for Basic and Enhanced areas with Bay Area in Basic	1.83	.30	2.13	2.65
Bay Area Enhanced Benefits	.96	.01	.97	.83
Statewide benefits for Basic and Enhanced areas with Bay Area in Enhanced	2.79	.31	3.1	3.48
Benefits (Adjusted for just Enhanced Areas)	2.43	.27	2.70	3.02

To estimate the emission benefits of replacing the 30-year rolling exemption with a pre-1966 exemption, ARB staff:

1. Ran EMFAC2002 for the entire State with the existing 30-year rolling exemption in 2010. In 2010, the existing 30-year rolling exemption would include 1982 to 2006 model-year vehicles in the Smog Check inspection program.
2. Ran EMFAC2002 with the proposed pre-1966 exemption in 2010. In 2010, the pre-1966 exemption would add the 1966-1981 model year vehicles to the Smog Check inspection program.
3. Subtracted pre-1966 exemption emissions from the 30-year rolling emissions.
4. Estimated the Bay Area enhanced I/M emission benefits in 2010 using the same methodology above.
5. Added the Bay Area enhanced I/M emission benefits to the pre-1966 exemption benefits from task 3 above.
6. Multiplied the sum from task 5 by the proportion of the State that is enhanced in 2010.

Table 1.4.3 displays the emission benefits of replacing the 30-year rolling exemption with a pre-1966 exemption.

Table 1.4.3

Benefits of Replacing 30-Year Rolling Exemption With a Pre-1966 Model Year Exemption (Retaining Model Years 1966-1981) Calendar Year 2010 Summer Season TPD				
	Exh. HC	Evap HC	Total HC	NOx
Emissions with current 30-year rolling exemption	263.45	242.32	505.77	1001.76
Emissions with pre-1966 exemption	256.14	239.06	495.2	995.59
Statewide benefits for Basic and Enhanced areas with Bay Area in Basic	7.31	3.26	10.57	6.17
Bay Area Enhanced Benefits	1.27	-0.01	1.26	1.10
Statewide benefits for Basic and Enhanced areas with Bay Area in Enhanced	8.58	3.25	11.83	7.27
Benefits (Adjusted for just Enhanced Areas)	7.46	2.83	10.29	6.33

Table 1.4.4 displays the incremental emission benefits of the pre-1966 exemption over the pre-1976 exemption.

Table 1.4.4

Benefits of Adding 1966-1975 Model Year Vehicles to the Program Calendar Year 2010 Summer Season TPD				
	Exh. HC	Evap HC	Total HC	NOx
Benefits of pre-1966 Exemption	7.46	2.83	10.29	6.33
Benefits of pre-1976 Exemption	2.43	.27	2.70	3.02
Benefits for Enhanced I/M Areas	5.03	2.56	7.59	3.30

1.5 Cost Effectiveness of Changing the 30-year Rolling Exemption

ARB staff estimated the cost effectiveness of changing the 30-year rolling exemption by determining the number of vehicles applicable to each option and the total cost of getting a Smog Check per vehicle. This total cost was divided by the emission benefits per I/M cycle.

To determine the number of vehicles for each option, ARB staff used EMFAC2002 version 2.2 (April 23, 2003) for the 2010 calendar year. To adjust the 2010 statewide numbers to just the enhanced areas, ARB staff used an adjustment factor of 87% for enhanced areas. BAR data showed that the Smog Check population would be 87% enhanced, 10% basic, and 3% change of ownership. Table 1.5.1 provides the vehicle population numbers used for the CE calculations.

Table 1.5.1

Vehicle Population Calendar Year 2010 Summer Season TPD		
	Statewide	Enhanced Areas
Total number in current Smog Check Program (1982-2006 model-years)	18,435,595	16,038,968
Total number 1966-1981 model-years	665,783	579,231
Total number 1966-1975 model-years	276,107	240,213
Total number 1976-1981 model-years	389,676	339,018

ARB staff assumed the following are included in the cost of getting a Smog Check inspection:

- Smog Check inspection cost for every vehicle.
- Repair costs for vehicles that fail the Smog Check inspection.

To determine the number of failing vehicles, ARB staff calculated an average failure rate based on data contained in the BAR Executive Summary report for Fiscal Year 2001-2002. This report lists initial test failure rates by model year. ARB staff used these data to calculate a simple average of the failure rates for model years 1976 through 1981. Since we do not have data on pre-1976 model years, ARB staff assumed that they will have a similar failure rate to 1976-81 vehicles. Table 1.5.2 displays the failure rates for each model year.

Table 1.5.2

I/M Failure Rate Fiscal Year 2001-2002 From BAR Executive Summary Report	
Model-Year	% Fail on Initial Test
1976	29.1
1977	28.9
1978	29.3
1979	31.0
1980	31.1
1981	33.9
Average of MY 76-81	30.6

ARB staff used inspection and repair costs from BAR's calendar year 2002 Executive Summary report:

- Average enhanced I/M inspection cost = \$45.83
- Average enhanced I/M area repair cost = \$143.18

To determine the CE of the pre-1976 exemption, ARB staff calculated the total cost of Smog Check per I/M cycle by totaling the cost of all vehicles and the additional cost for

vehicles that fail. The cost of all vehicles equaled the total number of vehicles for one I/M cycle multiplied by the Smog Check inspection cost:

$$339,018 \text{ vehicles} \times \$45.83/\text{vehicle} = \$15,537,195$$

The additional cost for failing vehicles equaled the failure rate multiplied by the number of vehicles multiplied by the repair cost:

$$.306 \times 339,018 \text{ vehicles} \times \$143.18/\text{vehicle} = \$14,853,423$$

$$\text{Total cost} = \$15,537,195 + \$14,853,423 = \$30,366,358$$

The CE equaled the total cost divided by the emission reductions over one I/M cycle (two years).

$$\text{CE} = \$30,366,358 / ((5.72 \text{ tpd ROG} + \text{NO}_x) \times 2 \times 365)$$

$$\text{CE} = \$7,268/\text{ton}$$

Table 1.5.3

Cost Effectiveness Estimate for Pre-1976 Exemption Calendar Year 2010	
Initial test failure rate (%)	30.6%
Total average ASM inspection cost	\$45.83
Average Enhanced I/M repair cost (\$/Vehicle)	\$143.18
Average test cost per vehicle (\$)	\$89.57
# of vehicles subject to I/M	339,018
Total cost per I/M cycle (\$)	\$30,366,358
ROG+NO _x benefits (tons/ I/M cycle)	4178
Cost Effectiveness (\$/Ton)	\$7,268/ton

Consumer/Industry Impact of Pre-1976 Exemption

To determine cost impacts for consumers and industry, ARB staff calculated the additional annual inspection cost for the consumer, the additional annual repair cost for the consumer, and the annual revenues generated for the Smog Check inspection industry in calendar year 2010.

$$\text{Additional Inspection Cost} = (339,018 \text{ vehicles} / 2 \text{ years in biennial cycle}) \times \$45.83$$

$$\text{Additional Inspection Cost to Consumers} = \$7,768,597$$

$$\text{Additional Repair Cost} = (339,018 \text{ vehicles} / 2 \text{ years in biennial cycle}) \times .306 \times \$143.18$$

$$\text{Additional Repair Cost to Consumers} = \$7,426,711$$

$$\text{Additional Revenue to Industry} = \$7,768,597 + \$7,426,711 = \$15,195,308$$

To determine the CE for pre-1966 exemption, ARB staff calculated the total cost of Smog Check per I/M cycle by totaling the cost of all vehicles and the additional cost for

vehicles that fail. The cost of all vehicles equaled the total number of vehicles for one I/M cycle multiplied by the Smog Check inspection cost:

$$579,231 \text{ vehicles} \times \$45.83/\text{vehicle} = \$26,546,157$$

The additional cost for failing vehicles equaled the failure rate multiplied by the number of vehicles multiplied by the repair cost:

$$.306 \times 579,231 \text{ vehicles} \times \$143.18/\text{vehicle} = \$25,377,894$$

$$\text{Total cost} = \$26,546,157 + \$25,377,894 = \$51,882,603$$

The CE equaled the total cost divided by the emission reductions over one I/M cycle (two years):

$$\text{CE} = \$51,882,603 / ((16.62 \text{ ROG} + \text{NO}_x) \times 2 \times 365)$$

$$\text{CE} = \$4,277/\text{ton}$$

Table 1.5.4

Cost Effectiveness Estimate for pre-1966 Exemption Calendar Year 2010	
Initial test failure rate (%)	30.6%
Total average ASM inspection cost	\$45.83
Average Enhanced I/M repair cost (\$/Vehicle)	\$143.18
Average test cost per vehicle (\$)	\$89.57
# of vehicles subject to I/M	579,231
Total cost per I/M cycle (\$)	\$51,882,603
ROG+NO _x benefits (tons/ I/M cycle)	12,130
Cost Effectiveness (\$/Ton)	\$4,277/ton

1.6 Emission Benefits of Annual Inspection for Vehicles Over 15 Years Old

ARB staff used EMFAC 2002 version 2.2 (released April 23, 2003) to analyze the benefits of annual inspections for vehicles over 15 years of age.⁴ ARB staff assumed that the annual inspections for vehicles over 15 years old would be implemented in January 2004, and that all other aspects of the current enhanced I/M program, including the 30 year rolling exemption for older vehicles, would remain in place. For 2005, ARB staff assumed model years 1977 through 1990 would be subject to the annual inspections, and for 2010, model years 1982 through 1995 would be subject to the annual inspections.

⁴ In EMFAC2002, a new vehicle is counted as model year one, and a 15-year-old vehicle is counted as model year 16. This analysis addresses vehicles for model years 16 and older (e.g., model years 1995 and previous in calendar year 2010).

To estimate the benefits, ARB staff:

1. Estimated the statewide benefits of annual inspections by using the I/M module in the model to switch between biennial and annual inspections for the model years that would be included in a rolling requirement.
2. Estimated the additional benefits of enhanced I/M in the Bay Area.
3. Adjusted the benefits to reflect the enhanced I/M areas.

Table 1.6.1 summarizes the results from EMFAC2002 for the current program and implementation of the annual inspection element.

Table 1.6.1

Statewide Benefits of Annual Inspections for Vehicles Over 15 Years Without Adjustments for Bay Area and Enhanced I/M Calendar Year 2005 and 2010 Summer Season TPD				
	2005		2010	
	ROG	NOx	ROG	NOx
Emissions with Current Smog Check Program	267.92	389.75	250.00	372.71
Emissions with rolling annual inspection for vehicles over 15 years old	258.99	376.78	241.33	355.31
Default Benefit w/o adjustments	8.93	12.97	8.67	17.4

The statewide default in EMFAC2002 reflects basic BAR90 I/M in the Bay Area. Since enhanced I/M is currently being implemented in the Bay Area, ARB staff adjusted the estimate of benefits for annual inspections to reflect enhanced I/M in the Bay Area. ARB staff made separate EMFAC runs for the Bay Area to assess the impact of enhanced I/M on the benefits of rolling annual inspections in that region. The resulting Bay Area adjustments are shown in Table 1.6.2.

Table 1.6.2

Bay Area Enhanced Benefits of Annual Inspections for Vehicles Over 15 Years Calendar Year 2005 and 2010 Summer Season TPD				
	2005		2010	
	ROG	NOx	ROG	NOx
Emissions for Basic with rolling annual inspection for vehicles over 15 years old	52.38	72.90	49.53	71.05
Emissions for Enhanced with rolling annual inspection for vehicles over 15 years old	49.64	68.82	47.35	67.24
Bay Area Benefit	2.69	4.01	2.14	3.75

Since EMFAC2002 includes both basic BAR90 I/M and enhanced I/M program areas, ARB staff adjusted the EMFAC2002 output to reflect just enhanced I/M areas. ARB staff used an adjustment factor of 87% for enhanced I/M areas. BAR data showed that the Smog Check population would be 87% enhanced, 10% basic, and 3% change of ownership. Table 1.6.3 includes the adjustment and the enhanced I/M benefits of requiring annual inspections for vehicles older than 15 years.

Table 1.6.3

Emission Benefits for Requiring Annual Inspections for Vehicles Over 15 Years Old Calendar Year 2005 and 2010 Summer Season TPD				
	2005		2010	
	ROG	NOx	ROG	NOx
Default Benefit w/o Adjustments	8.93	12.97	8.67	17.4
Bay Area Benefit	2.69	4.01	2.14	3.75
Total Statewide Benefit	11.62	16.98	10.81	21.15
Adjustment for Enhanced Portion of State	(1.51)	(2.21)	(1.41)	(2.75)
Annual Inspection Benefits (Adjusted for Enhanced Areas)	10.11	14.77	9.40	18.40

1.7 Cost Effectiveness of Annual Inspection of Vehicles Over 15 Years Old

ARB staff estimated the CE of requiring annual instead of biennial testing of vehicles older than 15 model years by determining the number of affected vehicles and the total cost of getting a Smog Check per vehicle. This total cost was divided by the emission benefits per I/M cycle. ARB staff calculated a CE separately for the current biennial program and the proposed annual program based on the benefits of each program beyond basic BAR90 I/M. ARB staff took the difference in the CE between these two programs to be the incremental cost per ton for the annual program. We multiplied the incremental cost per ton by the tons of benefit for the annual program over the basic BAR90 I/M program, to get a total incremental cost for the annual program. Next, we divided the total incremental cost by the incremental benefits of the annual program over the biennial program to get the CE of the incremental benefits in dollars per ton.

To determine the number of vehicles affected by an annual inspection of vehicles over 15 years older, ARB staff used EMFAC2002 version 2.2 (4/23/03) for the statewide 2005 and 2010 calendar years for the applicable model-year range. Table 1.7.1 provides the vehicle population numbers used for the CE calculations.

Table 1.7.1

Vehicle Population Over 15 Years Old Calendar Year 2005 and 2010 Summer Season TPD	
	Enhanced Areas
Total number applicable vehicles in 2005 1977-1990 model years	4,392,052
Total number applicable vehicles in 2010 1982-1995 model years	5,393,351

ARB staff assumed the following are included in the cost of getting a Smog Check inspection:

- Smog Check inspection cost for every vehicle.
- Repair costs for vehicles that fail the Smog Check inspection.

The annual inspection failure rate was estimated by taking the failure rate for the biennial program and proportionally increasing it by the ratio of annual benefits over biennial benefits, then dividing by two to get an average failure rate per year.

Table 1.7.2 lists initial test failure rates by model year. ARB staff used these data to calculate a simple average of the failure rates for model years 1974 through 1987.

Table 1.7.2

Biennial Inspection Failure Rate I/M Failure Rate Calendar Year 2002			
Model Year	# of Vehicles	Failure Rate	Weighted Ave. Failure Rate
1974	5304	30.04%	0.39%
1975	4959	35.64%	0.43%
1976	7525	34.44%	0.64%
1977	11283	34.52%	0.96%
1978	13751	35.63%	1.20%
1979	16969	38.32%	1.60%
1980	12189	38.87%	1.16%
1981	16000	41.39%	1.63%
1982	20027	41.01%	2.02%
1983	26965	40.37%	2.67%
1984	49966	41.06%	5.04%
1985	63252	38.76%	6.02%
1986	73487	34.74%	6.27%
1987	85570	34.39%	7.23%
Model Year 74-87	407247		37.2

To estimate an annual fail rate consistent with the benefits predicted by EMFAC2002, ARB staff:

1. Calculated an average biennial failure rate for vehicles over 15 years old based on data provided by BAR for calendar year 2002.
2. Multiplied the average biennial failure rate by the ratio of the annual benefits divided by the biennial benefits.
3. Divided by 2, since to get the same benefit, the percent vehicles required to fail in one year would be one half that required to fail over two years.

Biennial failure rate to achieve annual benefits = $37.2 \times (50.68/40.57) = 46.5$

Annual inspection failure rate = $(46.5)/2 = 23.3\%$

Table 1.7.3 provides the comparison of the benefits for the biennial and annual programs. ARB staff used EMFAC2002 version 2.2 (4/23/03) to estimate the ROG benefits for the summer season in 2005. ARB staff assumed the rolling annual inspection is implemented in January 2004. Since these values do not include the incremental benefit of enhanced I/M in the Bay Area, ARB staff calculated this benefit by subtracting the default benefit without adjustments (Table 1.6.3) from the annual inspection benefits adjusted for enhanced I/M areas (Table 1.6.3) to get an incremental benefit of 1.18 tpd ROG. We added the incremental Bay Area benefit to the benefits of annual inspection to get the adjusted benefits shown in Table 1.7.3.

Table 1.7.3

Program Comparison for Vehicles Over 15 Years Old Calendar Year 2005 Summer Season TPD	
	ROG
Emissions with Basic Program	308.49
Emissions with Biennial Enhanced Program	267.92
Benefits of Biennial Enhanced Program	40.57
Emissions with Basic Program	308.49
Emissions with annual inspection for vehicles over 15 years old	258.99
Benefits of Annual Inspection	49.50
Incremental Enhanced I/M Benefit in Bay Area of annual inspection for vehicles over 15 years old	1.18
Benefits of Annual Inspection Adjusted for just Enhanced Areas (Including Enhanced in the Bay Area)	50.68

ARB staff estimated the Calendar Year 2005 CE for the incremental benefits beyond the current biennial program for annual inspection of vehicles over 15 years old. The average enhanced I/M inspection cost of \$45.83 per test and average enhanced I/M repair cost of \$143.18 per vehicle used to calculate CE are based on data published in BAR's CY 2002 Executive Summary report.

To determine the CE of biennial and annual testing for vehicles over 15 years old, ARB staff calculated the total cost of Smog Check per I/M cycle by totaling the cost of all

vehicles and the additional cost for vehicles that fail. For biennial testing, the cost of all vehicles equaled the total number of vehicles for two years multiplied by the Smog Check inspection cost:

$$4,392,052 \text{ vehicles} \times \$45.83/\text{vehicle} = \$201,287,743$$

The additional cost for failing vehicles equaled the failure rate multiplied by the number of vehicles for two years multiplied by the repair cost:

$$.372 \times 4,392,052 \text{ vehicles} \times \$143.18/\text{vehicle} = \$233,933,690$$

$$\text{Total cost} = \$201,287,743 + \$233,933,690 = \$435,533,586$$

The CE equaled the total cost divided by the emission reductions over two years.

The ROG emission benefit from biennial enhanced I/M, 40.57 tpd, is specified in Table 1.7.3. Using the same methodology as shown in Table 1.7.3, the NOx benefit was calculated as 62.03 tpd.

$$\text{CE} = \$435,533,586 / ((40.57 \text{ tpd ROG} + 62.03 \text{ tpd NOx}) \times 2 \times 365)$$

$$\text{CE} = \$5,815/\text{ton}$$

Table 1.7.4

Cost Effectiveness Calculation for Biennial Inspection of Vehicles Over 15 Years Old Calendar Year 2005	
Initial test failure rate (%)	37.2%
Total average ASM inspection cost	\$45.83
Average Enhanced I/M repair cost (\$/Vehicle)	\$143.18
Average test cost per vehicle (\$)	\$99.16
# of vehicles subject to I/M	4,392,052
Total cost per I/M cycle (\$)	\$435,533,586
ROG+NOx benefits (tons/ I/M cycle)	74,898
Cost Effectiveness (\$/Ton)	\$5,815/ton

Using the same methodology as shown above for the biennial program, ARB staff calculated the CE of the annual inspections for vehicles over 15 years old. ARB staff calculated the total cost of Smog Check per I/M cycle by totaling the cost of all vehicles and the additional cost for vehicles that fail. The cost of all vehicles equals the total number of vehicles for one year multiplied by the Smog Check inspection cost:

$$4,392,052 \text{ vehicles} \times \$45.83/\text{vehicle} = \$201,287,743$$

The additional cost for failing vehicles equaled the failure rate multiplied by the number of vehicles for one year multiplied by the repair cost:

$$.233 \times 4,392,052 \text{ vehicles} \times \$143.18/\text{vehicle} = \$146,522,983$$

$$\text{Total cost} = \$201,287,743 + \$146,522,983 = \$347,604,427$$

The CE equaled the total cost divided by the emission reductions over one year.

The ROG emission benefit from annual enhanced I/M, 50.68 tpd, is specified in Table 1.7.3. Using the same methodology as shown in Table 1.7.3, the NOx benefit was calculated as 76.80 tpd:

$$\text{CE} = \$347,604,427 / ((50.68 \text{ tpd ROG} + 76.80 \text{ tpd NOx}) \times 365)$$

$$\text{CE} = \$7,470/\text{ton}$$

Table 1.7.5

Cost Effectiveness Calculation for Annual Inspection of Vehicles Over 15 Years Old Calendar Year 2005	
Initial test failure rate (%)	23.3%
Total average ASM inspection cost	\$45.83
Average Enhanced I/M repair cost (\$/Vehicle)	\$143.18
Average test cost per vehicle (\$)	\$79.18
# of vehicles subject to I/M	4,392,052
Total cost per I/M cycle (\$)	\$347,604,427
ROG+NOx benefits (tons/ I/M cycle)	46,532
Cost Effectiveness (\$/Ton)	\$7,470/ton

To determine the incremental cost of the annual inspection over biennial inspection of vehicles over 15 years, ARB staff:

1. Calculated the incremental cost effectiveness.
2. Calculated the incremental cost per I/M cycle.
3. Calculated the cost effectiveness of the incremental benefit.

$$\text{Incremental CE} = \$7,470 - \$5,815 = \$1,655/\text{ton}$$

$$\text{Incremental Cost per I/M Cycle} = \$1,655/\text{ton} \times 46,532 \text{ tons/I/M cycle} = \$77,018,506$$

$$\text{CE} = \$77,018,506 / ((10.11 \text{ tpd ROG} + 14.77 \text{ tpd NOx}) \times 365)$$

$$\text{CE} = \$8,479/\text{ton}$$

Table 1.7.6

Cost Effectiveness Calculation of Incremental Benefits of Annual over Biennial Inspection of Vehicles Over 15 Years Old Calendar Year 2005	
Incremental Cost of Annual Program (\$/Ton)	\$1,655
Total incremental cost per I/M cycle	\$77,018,506
ROG+NOx benefits (tons/ I/M cycle)	9,083
Cost Effectiveness (\$/Ton)	\$8,479/ton

Consumer/Industry Impact of Annual Inspection of Vehicles Over 15 Years Old

To determine the annual consumer/industry impact, ARB staff calculated the additional inspection cost for the consumer, the addition repair cost for the consumer, and the revenues generated for the Smog Check inspection industry.

Additional Inspection Cost = (4,392,052 vehicles/2 years in biennial cycle) X \$45.83

Additional Inspection Cost to Consumers = \$100,643,872

Additional Repair Cost = (4,392,052 vehicles/2 years in biennial cycle) X .233 X \$143.18

Additional Repair Cost to Consumers = \$73,261,492

Additional Revenue to Industry = \$100,643,872 + \$73,261,492 = \$173,905,364

1.8 Emission Benefits of Annual Inspection of Taxicabs

Estimates of the benefits of inspecting high annual mileage vehicles are based on results from inspections of taxicab fleets in the San Francisco and Los Angeles areas in 2002. ARB conducted over 1600 inspections on 1992-2002 model year taxicabs. A subset of taxis equipped with on-board diagnostics type II (OBD II) and tested under the Federal Test Procedure (FTP) was used to analyze benefits.

To calculate the emissions benefits for annual testing of taxicabs, ARB staff:

1. Estimated the emission benefits on per vehicle basis from annual testing.
2. Calculated the average failure rate from random inspections.
3. Estimated the annual average mileage per taxicab.
4. Applied the benefits to the entire taxicab fleet.

In the taxicab study (ARB Project 2R0202), failure rates varied from 22% for scheduled inspections to 39% for random inspections. ARB staff chose to use the failure rate for the post-1996 taxicabs equipped with OBD II that received a random inspection because it represented the vehicles that ARB tested using the FTP and would not be affected by pre-inspection repairs. Table 1.8.1 shows the results of the inspections for taxicabs equipped with OBD II malfunction indicator lights.

Table 1.8.1

Taxicab MIL Status (OBD II Vehicles)		
MIL ON	144	34%
MIL OFF	275	66%
Total Taxicabs	419	100%

ARB staff procured forty-three 1996 and newer OBD II equipped vehicles for emission testing at ARB's Haagen-Smit Laboratory (HSL). All the taxicabs were equipped with a malfunction indicator light (MIL). The emission tests were conducted following the Federal Test Procedure (FTP). Of the 43 taxicabs brought in for testing, 15 failed the Smog Check inspection because the OBD II MIL was "ON." ARB staff tested the failed vehicles, repaired the failed vehicles so the MIL light was OFF, and then re-tested them after the repair. Table 1.8.2 shows the average emissions data for the 15 vehicles in grams per mile (GPM) for the vehicles that failed after their repairs, and the emission benefits of the repairs.

Table 1.8.1

Taxicab FTP Testing Results			
HSL FTP Testing Results	HC GPM	NOx GPM	CO GPM
FTP Results pre-repairs MIL ON	0.307	0.710	5.070
FTP Results post-repairs MIL OFF	0.123	0.211	2.005
Emission Benefits of Repair	0.184	0.499	3.065

The project also tracked the mileage of 241 taxicabs, which accumulated 4,767 miles per month. ARB staff extrapolated this to 57,999 miles per year. California's taxicab fleet is estimated at 20,000 vehicles.

ARB staff calculated the emission reductions from more frequent inspections of taxicabs statewide as the product of the statewide number of taxicabs, the assumed failure rate, the emission reductions per repair, and each vehicle's annual mileage:

HC Benefits = 20,000 X (0.34 failure) X (0.184 GPM) X (57,999 miles/year) X (0.0005 tons/453.9 grams) X (1year/365 days) = **0.2 tpd HC**

NOx Benefits = 20,000 X (0.34 failure) X (0.499 GPM) X (57,999 miles/year) X (0.0005 tons/453.9 grams) X (1year/365 days) = **0.6 tpd NOx**

CO Benefits = 20,000 X (0.34 failure) X (3.065 GPM) X (57,999 miles/year) X (0.0005 tons/453.9 grams) X (1year/365 days) = **3.6 tpd CO**

Extension of Benefits to All High Annual Mileage Vehicles. Smog Check test data for 2002 indicated that 3% of the fleet accumulated 25,000 miles or more per year. To estimate an upper bound of benefits from more frequent inspections for the Smog Check fleet as a whole, staff multiplied this number of vehicles by the taxicabs' failure rate, emission reductions per repair, and annual mileage:

HC Benefits = 559,174 vehicles X (0.34 failure) X (0.184 GPM) X (57,999 miles/year) X (0.0005 tons/453.9 grams) X (1year/365 days) = **6.1 tpd HC**

NOx Benefits = 559,174 vehicles X (0.34 failure) X (0.499 GPM) X (57,999 miles/year) X (0.0005 tons/453.9 grams) X (1year/365 days) = **16.6 tpd NOx**

CO Benefits = 559,174 vehicles X (0.34 failure) X (3.065 GPM) X (57,999 miles/year) X (0.0005 tons/453.9 grams) X (1 year/365 days) = **102.0 tpd CO**

ARB staff recognizes that both the miles driven and driving patterns by the larger fleet of high annual mileage vehicles may not match those of taxicabs, and that actual benefits are likely to be somewhat lower than shown in this calculation.

1.9 Cost Effectiveness of Annual Inspection of Taxicabs

ARB staff used the emission benefits calculated in the previous section and estimates of the cost of additional inspections and failures to calculate the cost effectiveness of annual testing of taxicabs.

ARB staff obtained the inspection and repair costs used for the calculations from BAR's calendar year 2002 Executive Summary Report, and used the OBD II vehicle failure rate from ARB's taxicab fleet study.

Inspection cost: \$45.83

Repair cost: \$143.18

Taxicab OBD II failure rate: 34.0%

ARB staff calculated the total cost of Smog Check per I/M cycle by totaling the cost of testing all vehicles and the additional cost for vehicles that fail. The cost for all vehicles equaled the total number of vehicles multiplied by the Smog Check inspection cost:

20,000 vehicles X \$45.83/vehicle = \$916,600

The additional cost for failing vehicles equaled the failure rate multiplied by the number of vehicles multiplied by the repair cost:

.34 X 20,000 vehicles X \$143.18/vehicle = \$973,624

Total cost = \$916,600 + \$973,624 = \$1,890,224

The CE equaled the total cost divided by the annual emission reductions:

CE = \$1,890,224/(292 tons per year ROG + NOx)

CE = \$6,473/ton

Table 1.9.2

Cost Effectiveness Estimate for Annual Testing of Taxicabs Calendar Year 2002	
Initial test failure rate (%)	34.0%
Total average ASM inspection cost	\$45.83
Average Enhanced I/M repair cost (\$/Vehicle)	\$143.18
Average test cost per vehicle (\$)	\$94.51
# of vehicles subject to I/M	20,000
Total cost per I/M cycle (\$)	\$1,890,224
ROG+NOx benefits (tons/ I/M cycle)	189.8
Cost Effectiveness (\$/Ton)	\$9,959/ton

Consumer/Industry Impact of Annual Inspection of High Mileage Vehicles

To determine the consumer/Industry impact, ARB staff calculated the additional inspection cost for the consumer, the additional repair cost for the consumer, and the revenues generated for the Smog Check inspection industry.

ARB staff estimated that approximately 3% of the fleet (560,000 vehicles) are considered high mileage vehicles and accumulate over 25,000 miles annually. Since not all high mileage fleets are OBD II only, ARB staff used the overall average failure rate from our taxicab study, which was 27%.

Additional Inspection Cost = (560,000 vehicles/2 years in biennial cycle) X 45.83

Additional Inspection Cost to Consumers = \$12,832,400

Additional Repair Cost = (560,000 vehicles/2 years in biennial cycle) X .27 X 143.18

Additional Repair Cost to Consumers = \$10,824,408

Additional Revenue to Industry = \$12,832,400 + \$10,824,408 = \$23,656,808

California Enhanced I/M Program Evaluation
TECHNICAL SUPPORT DOCUMENT
PART 2

This portion of the Technical Support Document for the *Evaluation of the California Enhanced Vehicle Inspection and Maintenance (Smog Check) Program (April 2004)* summarizes the results of several technical analyses conducted by the Bureau of Automotive Repair (BAR) and Sierra Research, an independent contractor. Methodologies are explained in each of the following chapters:

- 2.1 Emission Reductions from the Current Enhanced I/M Program (grams per mile)
- 2.2 Impacts of Exemption of 5 and 6 year Old Vehicles
- 2.3 Evaluating Station Performance
- 2.4 Estimating the Emission Benefits from the Inspection of Smoking Vehicles

2.1 Emission Reductions from the Current Enhanced I/M Program (grams per mile)

This section describes the analyses performed to estimate the emission benefits from the Enhanced Smog Check Program in grams per mile. For analyzing the current program, two techniques are available: (1) evaluation of emissions tests from roadside pullover programs, and (2) evaluation of the results from an emissions model. The emissions benefits derived from these two techniques are described below.

2.1.1 Roadside Data Analysis

The random roadside tests are conducted by BAR with the assistance of the California Highway Patrol. Although the inspection is not mandatory, the majority of motorists pulled over participate in the program. The inspections are conducted by BAR personnel using a portable dynamometer. Both modes of the Acceleration Simulation Mode (ASM) test are run – the “ASM5015” and the “ASM2525”. On the ASM5015, the vehicle is run at 15 miles per hour at a load equivalent to 50% of the maximum load encountered on the Urban Dynamometer Driving Schedule (UDDS) used in the Federal Test Procedure (FTP) for vehicle certification. The ASM2525 is a 25 mile per hour test at a load equivalent to 25% of the maximum load encountered on the FTP. On the ASM test procedure, tailpipe pollutant concentrations are measured (i.e., ppm for HC and NO_x, percent for CO). Thus, as discussed in detail below, correlation equations have been developed to convert the ASM test results into units of grams per mile (g/mi).

Summary of Available Roadside Data - As noted in the main report, there are two sources of roadside data that can be analyzed to estimate the effectiveness of the Enhanced program: (1) the 1999 Roadside Data; and (2) the 2002 Roadside Data. Specifics of these datasets are summarized below.

- *1999 Roadside Data* - This program was conducted from February 1997 through October 1999. Approximately 27,000 test records were collected over this two and a half year period. The roadside records were then matched with Smog Check records to determine whether the vehicles were subject to an ASM test or a Two-Speed Idle (TSI) test prior to the roadside inspection. Figure 2.1 shows the monthly count of roadside inspections and Figure 2.2 shows the model year distribution of vehicles in the dataset. Note that only vehicles with matching Smog Check records are included in these figures.
- *2002 Roadside Data* - Conducted between January 2000 and October 2002, approximately 13,000 vehicles were tested, and nearly 12,000 of those were able to be matched up with prior Smog Check Records. The monthly count of roadside test records for this program is shown in Figure 2.3, while the distribution of model years is included in Figure 2.4.

Figure 2.1
Histogram of Test Dates for the
"1999 Roadside" Data
Only Vehicles with Matching Smog Check Records

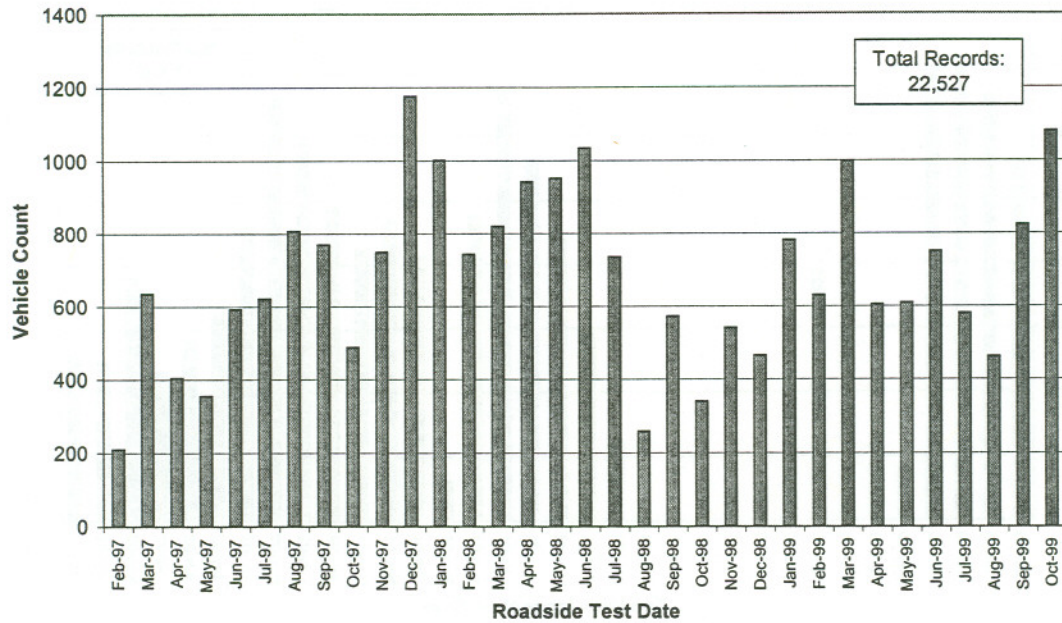


Figure 2.2
Histogram of Vehicle Model Years Included
in the "1999 Roadside" Data
Only Vehicles with Matching Smog Check Records

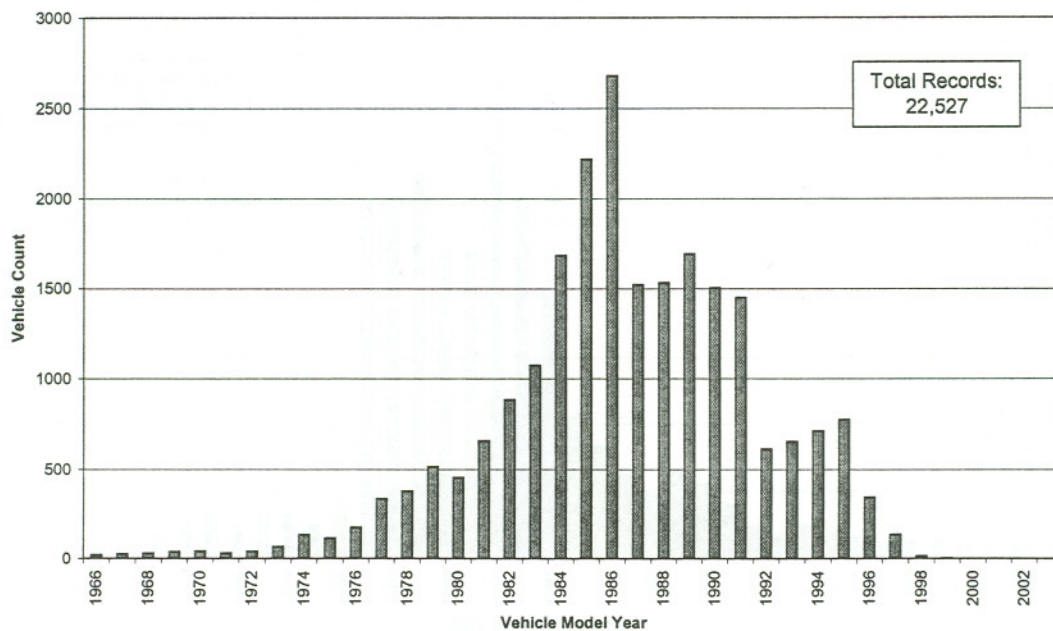


Figure 2.3
Histogram of Test Dates for the
"2002 Roadside" Data
Only Vehicles with Matching Smog Check Records

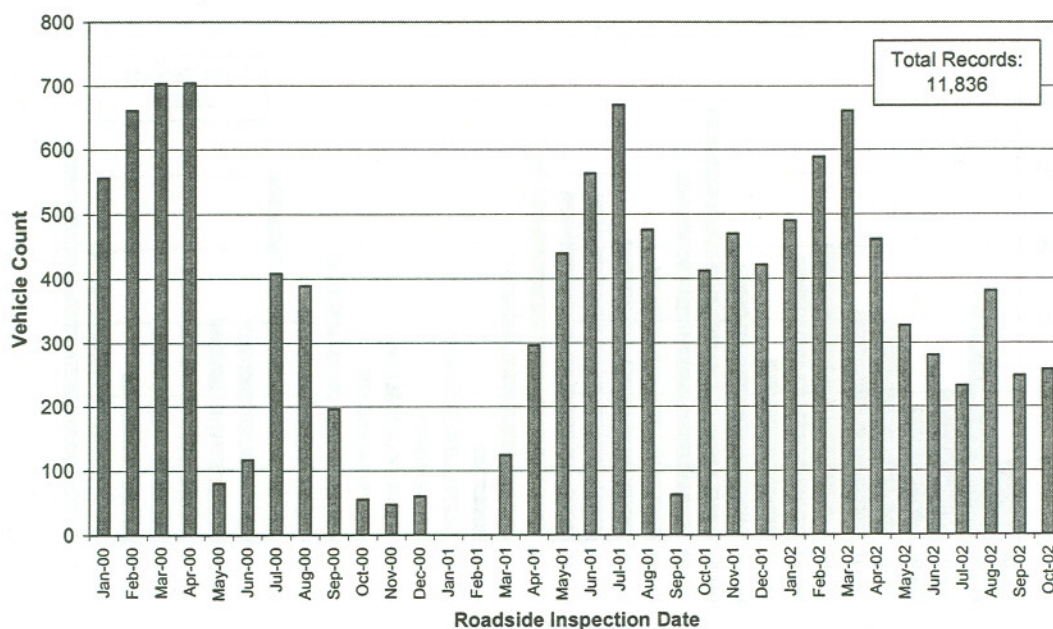
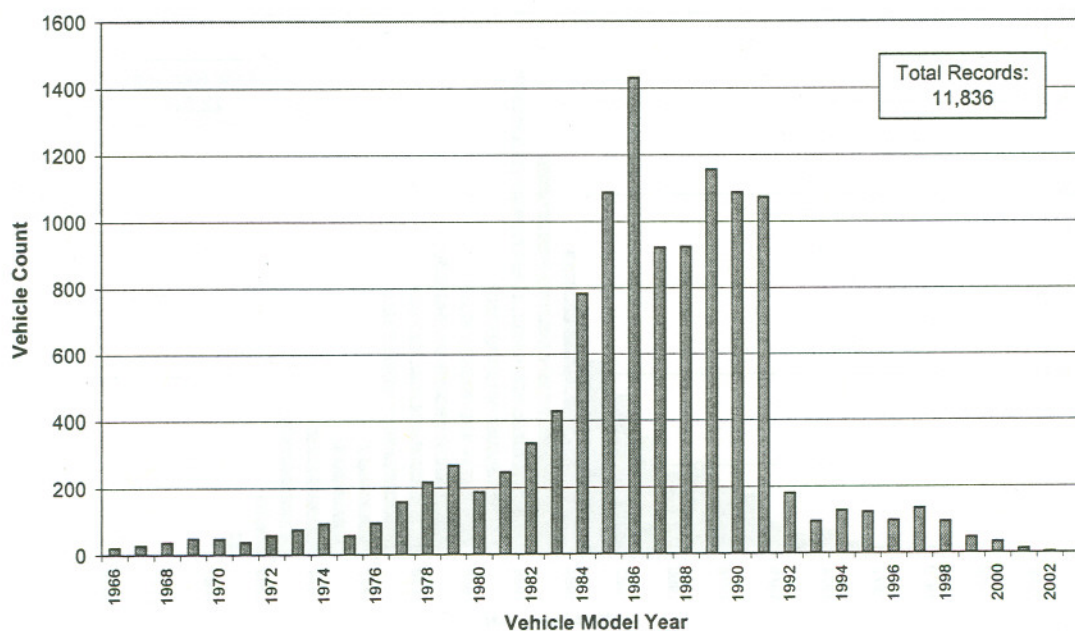


Figure 2.4
Histogram of Vehicle Model Years Included
in the "2002 Roadside" Data
Only Vehicles with Matching Smog Check Records



Methodology - In the July 2000 evaluation of program effectiveness, the Air Resources Board (ARB) was able to use the 1999 Roadside Program data to compare emissions results from vehicles that had been through the ASM test procedure at a Smog Check station ("After ASM") to emissions from vehicles that had not yet received an ASM inspection ("Before ASM"). These two groups of vehicles were identified by merging official Smog Check records from California's Vehicle Information Database (VID) with the 1999 Roadside data based on matching Vehicle Identification Numbers (VINs) and license plates. Because the time period over which the 1999 Roadside data were collected was during implementation of the BAR97 ASM test in Enhanced I/M program areas, there were an adequate number of vehicles that fell into both the Before ASM and After ASM groups. As noted in the July 2000 report, only vehicles tested from November 11, 1998, through October 29, 1999, were included in the analysis. That limitation was placed on the data because of concerns that vehicles of the same model year tested at the beginning of the program may not be comparable to the same model year vehicles at the end of the program (as a result of emission control system deterioration). In addition, only vehicles with matching data that could be identified were included in the analysis.

Given the above constraints, the following groups of vehicles were used in the July 2000 analysis of program effectiveness:

- After ASM - These vehicles had completed the ASM test requirements prior to the roadside inspection, either passing the ASM test at a Smog Check station or failing the ASM test at a Smog Check station. This group consisted of 4,233 test records.
- Before ASM - These vehicles had not completed the ASM test requirements prior to the roadside inspection, having been subject to the TSI test used prior to implementation of the Enhanced I/M program requirements. This group consisted of 5,232 test records.

A comparison of the Before and After ASM groups in the July 2000 analysis indicated that the enhanced ASM test procedure was achieving benefits of 14% for HC, 13% for CO, and 6% for NOx relative to the TSI test procedure.

Analysis of the 2002 Roadside data is complicated by the fact that most vehicles should have been through at least one I/M cycle with the BAR97 ASM test procedure. Although there are a number of vehicles in the 2002 Roadside database that received a TSI test prior to the roadside test, those vehicles are in the minority. As a result, the benefits of the current BAR97 ASM program must be evaluated by comparing the 2002 Roadside data for vehicles that had been tested over the ASM procedure ("2002 After ASM") to the 1999 Roadside data for vehicles that had not been tested with the ASM procedure ("1999 Before ASM"). However, because of the three-year difference in when the roadside data were collected, the 1999 Before ASM data must be forecast to a 2002 basis to account for anticipated emission control system deterioration between 1999 and 2002. The approach used to forecast those emissions is discussed later in this section.

Consistent with the July 2000 analysis, data from the 2002 Roadside Program were analyzed as follows:

- For 1974 through 1998 model year vehicles (i.e., the population subject to ASM testing), only test records that had received an ASM test prior to the roadside inspection were included in the analysis;
- For pre-1974 and 1999 through 2002 model year vehicles all test records were combined by model year (these model years reflect vehicles that are not subject to the enhanced program); and
- Only Roadside data collected from October 1, 2001, through October 31, 2002, were included in the analysis.

Table 2.1 summarizes the mean ASM scores by model year from the 2002 Roadside data for vehicles that had been subject to BAR97 ASM testing, subject to the constraints outlined above. As observed in that table, significantly lower average tailpipe emissions (as measured with the ASM test procedure) are being recorded from the newer vehicles in the fleet. In addition to the mean ASM scores, the 95% confidence interval for the mean ASM estimate is also presented. This was calculated based on the methodology presented in the July 2000 evaluation of the Smog Check program.

Because the results in Table 2.1 reflect emissions with the enhanced program implemented, ideally those results would be compared to roadside ASM scores from vehicles subject to the TSI program. The difference between the two sets of numbers would provide an indication of the benefits of the enhanced versus the basic program. However, as discussed above, because the majority of vehicles in the 2002 Roadside database had already been tested with the enhanced BAR97 procedure in their Smog Check inspection immediately prior to the roadside test, the 2002 Roadside data cannot be used to develop the baseline for comparison to the BAR97 results. Instead, the basic program results from the 1999 Roadside data were used for this comparison. However, those results had to be forecast to a 2002 basis. As explained below, this was done by determining the increase in emissions over three years (from 1999 to 2002) as predicted by EMFAC2002 under a basic I/M program. Because the EMFAC2002 analysis was based on FTP-equivalent emissions, the Roadside ASM data (both 1999 and 2002 databases) were first converted to an FTP basis.

Table 2.1

Fleet-Average ASM Emissions Concentrations for Vehicles in the 2002 Roadside Database
1974 - 1998 Model Year Vehicles Were Subject to the BAR97 ASM Test Procedure Prior to the Roadside Test

Model Year	Number Tested	ASM5015 Roadside Results						ASM2525 Roadside Results						EMFAC2002 Travel Fraction
		Mean HC (ppm)		Mean CO (%)		Mean NOx (ppm)		Mean HC (ppm)		Mean CO (%)		Mean NOx (ppm)		
1966	19	378	+/- 294	2.08	+/- 0.96	1179	+/- 362	391	+/- 327	2.11	+/- 1.07	1039	+/- 335	0.0036
1967	20	222	+/- 44	2.81	+/- 1.15	1196	+/- 426	215	+/- 45	2.87	+/- 1.09	1057	+/- 362	0.0009
1968	29	176	+/- 32	2.22	+/- 0.83	1051	+/- 250	174	+/- 33	2.23	+/- 0.82	982	+/- 246	0.0011
1969	45	297	+/- 202	2.00	+/- 0.60	1259	+/- 264	267	+/- 202	2.07	+/- 0.63	1119	+/- 251	0.0015
1970	30	173	+/- 25	1.86	+/- 0.73	1212	+/- 286	167	+/- 28	1.77	+/- 0.72	1134	+/- 316	0.0016
1971	37	375	+/- 316	1.34	+/- 0.46	1270	+/- 188	363	+/- 309	1.41	+/- 0.47	1109	+/- 191	0.0016
1972	44	201	+/- 85	2.04	+/- 0.66	947	+/- 209	197	+/- 96	2.02	+/- 0.66	844	+/- 184	0.0022
1973	44	278	+/- 175	2.14	+/- 0.78	1060	+/- 218	270	+/- 168	2.30	+/- 0.81	947	+/- 199	0.0024
1974	31	254	+/- 176	1.70	+/- 0.91	1012	+/- 301	249	+/- 182	1.68	+/- 0.93	878	+/- 236	0.0016
1975	18	148	+/- 72	0.87	+/- 0.69	1239	+/- 349	145	+/- 76	0.87	+/- 0.70	1120	+/- 331	0.0013
1976	25	213	+/- 179	1.28	+/- 0.55	862	+/- 213	169	+/- 119	1.29	+/- 0.55	741	+/- 195	0.0019
1977	49	198	+/- 225	0.97	+/- 0.52	826	+/- 153	192	+/- 225	1.02	+/- 0.50	697	+/- 146	0.0028
1978	67	167	+/- 81	1.74	+/- 0.55	610	+/- 129	156	+/- 75	1.80	+/- 0.57	528	+/- 114	0.0034
1979	98	161	+/- 67	0.94	+/- 0.40	737	+/- 132	143	+/- 62	0.93	+/- 0.41	647	+/- 119	0.0043
1980	53	112	+/- 41	1.01	+/- 0.51	823	+/- 196	101	+/- 33	1.05	+/- 0.53	707	+/- 167	0.0035
1981	78	98	+/- 23	1.03	+/- 0.52	812	+/- 181	82	+/- 18	0.91	+/- 0.42	685	+/- 164	0.0043
1982	107	94	+/- 17	0.99	+/- 0.42	648	+/- 120	83	+/- 17	1.01	+/- 0.42	524	+/- 91	0.0056
1983	151	96	+/- 16	0.92	+/- 0.31	661	+/- 108	86	+/- 17	0.94	+/- 0.32	544	+/- 90	0.0073
1984	238	108	+/- 31	0.82	+/- 0.22	767	+/- 99	91	+/- 24	0.72	+/- 0.21	653	+/- 93	0.0130
1985	367	92	+/- 12	0.72	+/- 0.17	631	+/- 60	76	+/- 11	0.71	+/- 0.17	530	+/- 53	0.0177
1986	471	78	+/- 7	0.65	+/- 0.13	716	+/- 71	68	+/- 15	0.57	+/- 0.12	610	+/- 60	0.0232
1987	353	85	+/- 13	0.66	+/- 0.17	640	+/- 74	71	+/- 13	0.63	+/- 0.17	525	+/- 64	0.0273
1988	361	60	+/- 7	0.31	+/- 0.11	530	+/- 62	49	+/- 7	0.33	+/- 0.12	454	+/- 53	0.0308
1989	507	54	+/- 5	0.25	+/- 0.06	451	+/- 47	44	+/- 5	0.23	+/- 0.06	389	+/- 45	0.0377
1990	478	51	+/- 16	0.20	+/- 0.07	363	+/- 41	40	+/- 13	0.20	+/- 0.07	304	+/- 34	0.0381
1991	481	47	+/- 7	0.20	+/- 0.06	344	+/- 39	34	+/- 5	0.18	+/- 0.06	285	+/- 32	0.0413
1992	122	41	+/- 8	0.15	+/- 0.04	330	+/- 93	34	+/- 8	0.20	+/- 0.10	296	+/- 83	0.0387
1993	53	30	+/- 15	0.22	+/- 0.29	258	+/- 108	22	+/- 11	0.10	+/- 0.07	249	+/- 101	0.0462
1994	67	22	+/- 6	0.05	+/- 0.02	201	+/- 62	18	+/- 5	0.06	+/- 0.03	189	+/- 58	0.0516
1995	70	16	+/- 5	0.05	+/- 0.02	165	+/- 49	14	+/- 7	0.04	+/- 0.02	180	+/- 54	0.0610
1996	55	10	+/- 3	0.03	+/- 0.01	93	+/- 32	9	+/- 3	0.04	+/- 0.01	80	+/- 31	0.0563
1997	65	8	+/- 2	0.02	+/- 0.01	76	+/- 27	7	+/- 2	0.03	+/- 0.01	76	+/- 28	0.0667
1998	25	7	+/- 2	0.02	+/- 0.01	138	+/- 216	6	+/- 3	0.03	+/- 0.02	129	+/- 193	0.0685
1999	79	7	+/- 3	0.01	+/- 0.00	58	+/- 51	7	+/- 2	0.02	+/- 0.00	67	+/- 46	0.0777
2000	59	5	+/- 1	0.02	+/- 0.00	40	+/- 30	5	+/- 1	0.01	+/- 0.00	32	+/- 25	0.0793
2001	65	5	+/- 1	0.01	+/- 0.00	9	+/- 5	5	+/- 1	0.01	+/- 0.00	24	+/- 24	0.0838
2002	18	6	+/- 2	0.01	+/- 0.01	33	+/- 62	6	+/- 2	0.01	+/- 0.00	33	+/- 52	0.0899
Wtd Average	4879	32	+/- 10	0.19	+/- 0.07	237	+/- 68	28	+/- 10	0.19	+/- 0.07	211	+/- 63	1.0000

that were not subject to the BAR97 ASM test procedure prior to the roadside test.

FTP-Based Analysis of the Roadside Data - The ASM concentration data collected in the 1999 and 2002 Roadside programs were converted to predicted FTP emission rates (in grams per mile) using correlation equations that were newly developed for this study. The general approach for developing the correlations followed closely the methodology developed by Radian/ERG for the July 2000 Smog Check evaluation.¹ However, a new dataset was used for this analysis that included additional ASM-FTP test results, particularly for late-model vehicles (i.e., 1996 and newer model year vehicles). The 1999 ERG analysis used a dataset with test scores for 1,372 vehicles, while the current analysis was based on a dataset with test scores for 1,934 vehicles. In addition, separate equations were developed for pre-1990 and 1990+ model year vehicles in the current analysis. Appendix 2A contains a summary of the ASM-to-FTP correlation equations developed for this effort.

The ASM-to-FTP correlation equations presented in Appendix 2A were applied to the roadside ASM test measurements to develop predicted FTP scores for each vehicle in the 1999 and 2002 Roadside databases. Mean emission rates were developed for each model year separately for the “1999 Before ASM” sample and the “2002 After ASM” sample. The model-year-specific FTP-based emissions from the “1999 Before ASM” sample were then forecast to a 2002 basis using results from the EMFAC2002 model in which vehicle emission rates were compared at three years apart. For example, a 1985 model year vehicle would be 14 years old in 1999 and 17 years old in 2002. According to EMFAC2002, the applicable FTP-based HC emission rates for such a vehicle subject to BAR90 I/M would be:

- 1985 MY @ 14 years (CY1999) = 1.474 g/mi
- 1985 MY @ 17 years (CY2002) = 1.525 g/mi

and the ratio of the 17-year emission rate to the 14-year emission rate is $1.525/1.474 = 1.035$. Thus, the mean HC emission rate for 1985 model year vehicles in the “1999 Before ASM” sample was multiplied by 1.035 to account for an additional three years of deterioration. These adjustments, which are presented in Appendix 2B, were applied to 1974 through 1998 model year vehicles from the “1999 Before ASM” sample.

The resulting FTP emission rates for the “1999 Before ASM” sample, adjusted to a 2002 basis, and the “2002 After ASM” sample are shown in Table 2.2. The emission rates for each model year were multiplied by the EMFAC2002 travel fraction shown in the table (calculated for calendar year 2002 on a statewide basis), and the sum of those products gave the fleet-average emission rates shown at the bottom of Table 2.2. Several items are worth noting with respect to the estimates contained in the table:

Table 2.2

Fleet-Average Predicted FTP Emission Rates from the 1999 and 2002 Roadside Data
1999 Roadside Data Forecast to a 2002 Basis

Model Year	1999 Roadside FTP Values Forecast to 2002 BAR90 I/M Stringency ("Before ASM")				2002 Roadside FTP Values BAR97 I/M Stringency ("After ASM")				Percent Emission Reduction by Model Year			EMFAC2002 Travel Fraction
	(n)	HC (g/mi)	CO (g/mi)	NOx (g/mi)	(n)	HC (g/mi)	CO (g/mi)	NOx (g/mi)	HC	CO	NOx	
1966	19	12.34	119.4	2.67	19	12.34	119.4	2.67	0%	0%	0%	0.0036
1967	20	10.50	137.8	2.59	20	10.50	137.8	2.59	0%	0%	0%	0.0009
1968	29	9.19	121.8	2.75	29	9.19	121.8	2.75	0%	0%	0%	0.0011
1969	45	9.54	112.3	3.21	45	9.54	112.3	3.21	0%	0%	0%	0.0015
1970	30	7.97	101.8	3.01	30	7.97	101.8	3.01	0%	0%	0%	0.0016
1971	37	8.25	86.2	2.97	37	8.25	86.2	2.97	0%	0%	0%	0.0016
1972	44	7.48	100.4	2.74	44	7.48	100.4	2.74	0%	0%	0%	0.0022
1973	44	7.46	98.4	2.80	44	7.46	98.4	2.80	0%	0%	0%	0.0024
1974	29	7.01	76.1	2.93	31	5.69	67.0	2.30	19%	12%	21%	0.0016
1975	21	4.78	63.7	2.53	18	4.84	53.8	3.17	-1%	16%	-25%	0.0013
1976	32	5.46	53.4	2.61	25	4.74	62.0	2.39	13%	-16%	8%	0.0019
1977	71	4.86	54.5	2.46	49	3.52	43.4	2.19	28%	20%	11%	0.0028
1978	78	4.76	49.2	2.68	67	3.81	54.9	1.84	20%	-12%	31%	0.0034
1979	91	3.63	42.1	2.29	98	2.96	32.5	1.95	18%	23%	15%	0.0043
1980	89	2.92	44.7	1.95	53	2.35	31.2	1.74	19%	30%	11%	0.0035
1981	102	3.04	43.1	1.83	78	2.07	26.6	1.70	32%	38%	7%	0.0043
1982	130	2.56	34.8	1.75	107	1.89	25.5	1.42	26%	27%	19%	0.0056
1983	186	2.50	30.9	2.05	151	1.83	24.6	1.47	27%	20%	28%	0.0073
1984	288	2.40	31.3	1.73	238	1.74	21.7	1.57	27%	31%	9%	0.0130
1985	403	1.90	24.1	1.67	367	1.52	19.5	1.37	20%	19%	18%	0.0177
1986	454	1.51	19.5	1.53	471	1.33	17.3	1.38	12%	11%	10%	0.0232
1987	416	1.40	18.8	1.43	353	1.28	16.6	1.25	9%	11%	13%	0.0273
1988	376	1.24	15.1	1.35	361	0.97	11.6	1.10	22%	23%	18%	0.0308
1989	454	0.96	11.9	1.10	507	0.87	10.6	1.00	10%	12%	10%	0.0377
1990	398	0.72	9.0	0.89	478	0.64	7.6	0.81	10%	15%	10%	0.0381
1991	409	0.61	7.5	0.83	481	0.54	7.1	0.77	11%	6%	8%	0.0413
1992	119	0.71	7.4	0.81	122	0.48	6.4	0.72	32%	14%	10%	0.0387
1993	125	0.45	5.4	0.62	53	0.39	5.1	0.63	15%	6%	-1%	0.0462
1994	132	0.42	4.8	0.62	67	0.30	4.0	0.55	27%	17%	11%	0.0516
1995	225	0.40	4.4	0.54	70	0.24	3.3	0.45	40%	26%	16%	0.0610
1996	232	0.29	3.7	0.39	55	0.19	2.5	0.33	37%	32%	15%	0.0563
1997	61	0.27	2.8	0.32	65	0.15	2.0	0.27	45%	30%	16%	0.0667
1998	64	0.20	2.2	0.23	25	0.13	1.6	0.24	38%	27%	-5%	0.0685
1999	79	0.12	1.4	0.18	79	0.12	1.4	0.18	0%	0%	0%	0.0777
2000	59	0.09	1.1	0.14	59	0.09	1.1	0.14	0%	0%	0%	0.0793
2001	65	0.08	0.8	0.09	65	0.08	0.8	0.09	0%	0%	0%	0.0838
2002	18	0.06	0.6	0.08	18	0.06	0.6	0.08	0%	0%	0%	0.0899
Wtd Average	5474	0.70	8.5	0.62	4879	0.59	7.3	0.56	16%	14%	10%	1.000

Notes:

Emission rates for pre-1974 and 1999+ model year vehicles were set equal to each other for the Before ASM and the After ASM samples for the following reasons:

- Pre-1974 model years were exempt from I/M requirements
- 1999 and newer model years were exempt from I/M requirements

- The pre-1974 model year vehicle emission rates and the 1999 and newer model year vehicle emission rates for the Before ASM and After ASM samples were set equal to each other and were based on all vehicles in the 2002 Roadside database. This was done because these vehicles are exempt from the biennial I/M requirements.
- As a result of the above assumptions, the sample sizes for the 1974 through 1998 model year vehicles are consistent with the "Before BAR97 ASM Smog Check Inspection" dataset presented in the July 2000 Smog Check evaluation report (see Tables III-3 and A-2 of that report).

Results of Roadside Data Analysis – Table 2.3 summarizes the fleet-average FTP-based emissions results from the Roadside data analysis described above.

Table 2.3
Fleet-Average FTP Estimates Based on Roadside Data Analysis

Analysis	I/M Scenario	HC	CO	NOx
Current (Based on 2002 and 1999 Roadside Data)	Before ASM (g/mi)	0.700	8.50	0.620
	After ASM (g/mi)	0.590	7.30	0.560
	Percent Reduction	16%	14%	10%

Adjustment for Two-Speed Idle (TSI) Testing in Enhanced Areas - The benefits of ASM testing presented in Table 2.3 assume that all vehicles subject to ASM testing in Enhanced areas actually receive an ASM test. However, there are conditions under which inspectors can perform a TSI test on a vehicle normally subject to ASM testing. Legitimate reasons include vehicles equipped with full-time four wheel-drive, vehicles with traction control that cannot be disabled, and non-enhanced vehicles being tested in enhanced areas, etc. Inspectors may also incorrectly perform a TSI test on 2WD testable vehicles in Enhanced areas. As a result, the benefits of ASM testing summarized in the table need to be adjusted to account for such TSI testing rather than simply applying them to the entire fleet of vehicles operating in Enhanced areas.

The fraction of vehicles receiving TSI tests in Enhanced I/M areas was determined by evaluating both the 2001-2002 Roadside data and the July 2002 Smog Check VID data. Of those vehicles identified as receiving an ASM or TSI test as their Smog Check inspection prior to the 2001 - 2002 Roadside test (1974 - 1978 only), 12% received a TSI test. A check of the July 2002 VID data for Enhanced areas showed similar results, with 14% of non-heavy duty vehicles (which were not subject to ASM testing in 2002) receiving TSI tests; i.e., 86% received an ASM test.

An additional adjustment was also needed to account for legitimate TSI tests performed in the Enhanced areas on vehicles registered in non-Enhanced areas, which are totally

excluded from the analysis of Enhanced program benefits. BAR provided April 2003 VID results which included test counts of ASM Exempt Reasons, which showed that 74.1% of TSI tests of non-HDVs in the Enhanced areas was due to the vehicle being registered in Basic or Change-of-Ownership areas. The 14% TSI fraction observed in the July 2002 VID data (a more robust sample) was therefore multiplied by 25.9% to calculate the appropriate TSI adjustment factor of 3.6%.

These results were used to adjust the "After-ASM" results presented previously such that 96.4% of the fleet was assumed to have received an ASM test ("After ASM" in Table 2.3) and 3.6% was assumed to have the same emission rate as the "Before ASM" fleet (i.e., TSI) in the table. This assumption was made because there is not enough information to determine if the vehicles currently receiving TSI tests have significantly different emissions characteristics than vehicles reflected in the TSI baseline developed from the 1999 Roadside data.

The results of the above analysis are presented in Table 2.4, which shows the percentage of non-heavy duty Enhanced area vehicles receiving a TSI test to be small enough so that this adjustment results in no difference in the g/mi results previously presented in Table 2.3 when they are shown to three significant digits. There is a slight change in the calculated percentage reductions, with HC and NOx benefits dropping by one percentage point each.

Table 2.4
Fleet-Average FTP Estimates Based on 2002 Roadside Data Analysis and
Adjusted for TSI Testing in Enhanced Areas

Scenario	I/M Scenario	HC	CO	NOx
All Vehicles Receive an ASM Test (from Table 2.3)	Before ASM (g/mi)	0.700	8.50	0.620
	After ASM (g/mi)	0.590	7.30	0.560
	Percent Reduction	16%	14%	10%
96.4% of Enhanced Area Vehicles Receive an ASM Test	Before ASM (g/mi)	0.700	8.50	0.620
	After ASM (g/mi)	0.594	7.34	0.562
	Percent Reduction	15%	14%	9%

2.1.2 Comparison of Roadside and EMFAC2002 Modeling Results

To provide the closest comparison to roadside data, the EMFAC2002* model was run under the "CALIMFAC" mode, and FTP-based emission factors were requested (without temperature, speed, and other correction factors applied). Table 2.5 summarizes the FTP-based fleet-average emissions results from both approaches. Of note in that table is that the emissions estimates, both in terms of fleet-average gram-per-mile emission rates and percent reductions, are relatively consistent between the two very different approaches that were used to estimate the enhanced ASM benefits relative to the basic TSI program. Although the Roadside data show lower fleet-average emissions, the reductions from enhanced ASM testing are very close when comparing the two sets of estimates.

To serve as another comparison point, Figures 2.5, 2.6 and 2.7 show the model-year-specific FTP-based emission rates generated from EMFAC2002 (based on BAR97 I/M) on the same graph as the "After ASM" results from the 2002 Roadside data for HC, CO, and NOx, respectively. Reasonably good agreement is observed in all cases, with the EMFAC2002 model predicted values for HC and CO being higher than the Roadside data in the late-1980s to mid-1990s model years. This is likely a result of improved durability of in-use vehicles that is not reflected in the model. For older model year vehicles (i.e., pre-1980 model year), the Roadside data show higher HC and CO emissions than the EMFAC2002 model predicts.

Table 2.5
Comparison of BAR97 Emissions Benefits in Calendar Year 2002
Based on the Roadside Data Analysis and the EMFAC2002 Model
(FTP-Based Emission Rates)

Analysis	I/M Scenario	HC	CO	NOx
Current Roadside Data Analysis	Before ASM (g/mi)	0.70	8.5	0.62
	After ASM (g/mi)	0.59	7.3	0.56
	Percent Reduction	15%	14%	9%
EMFAC2002 (Passenger Cars; Lt- and Med-Duty Trucks)	Before ASM (g/mi)	0.83	9.5	0.75
	After ASM (g/mi)	0.72	8.1	0.66
	Percent Reduction	13%	15%	12%

*The EMFAC2002 emissions model is described in Part 1 of this document.

Figure 2.5

Comparison of the 2002 Roadside FTP Estimates to EMFAC2002 FTP Estimates
Exhaust HC Emissions With the BAR97 I/M Program

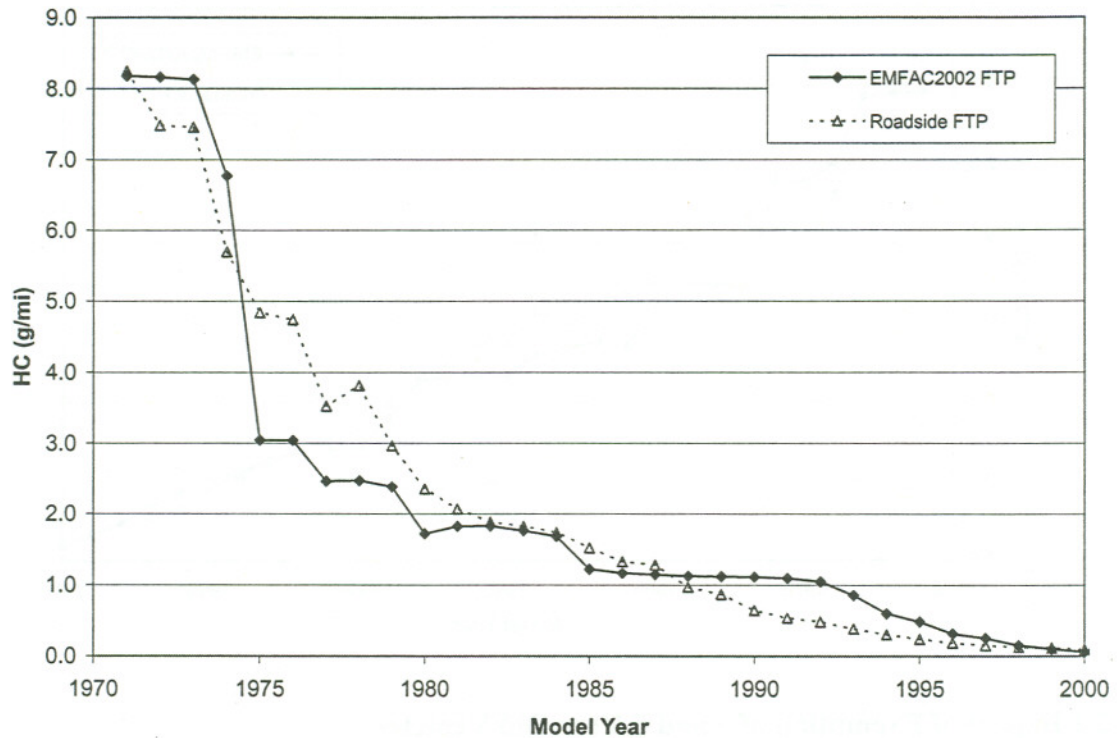


Figure 2.6

Comparison of the 2002 Roadside FTP Estimates to EMFAC2002 FTP Estimates
CO Emissions With the BAR97 I/M Program

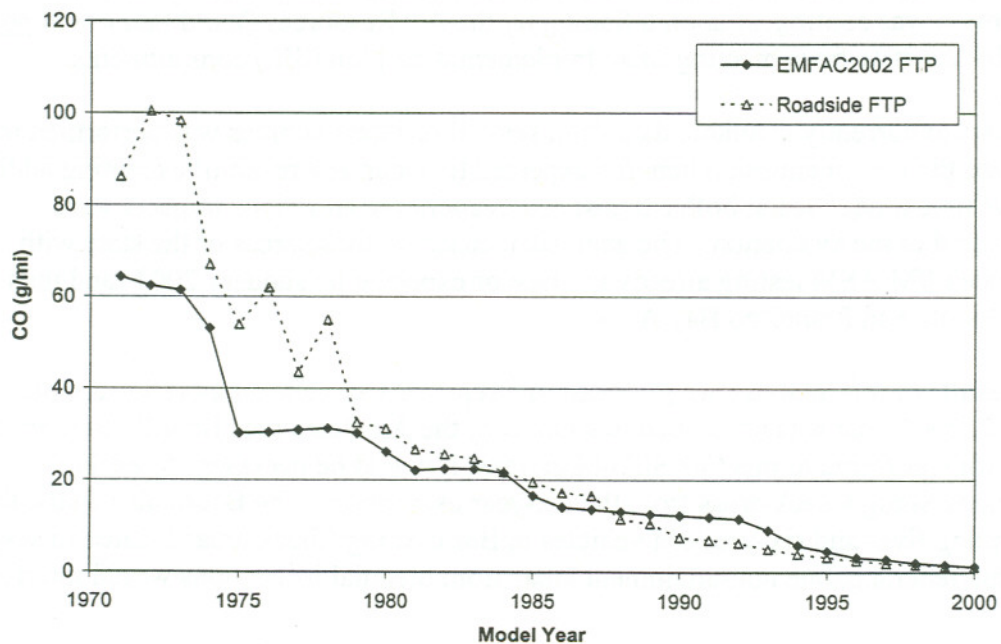
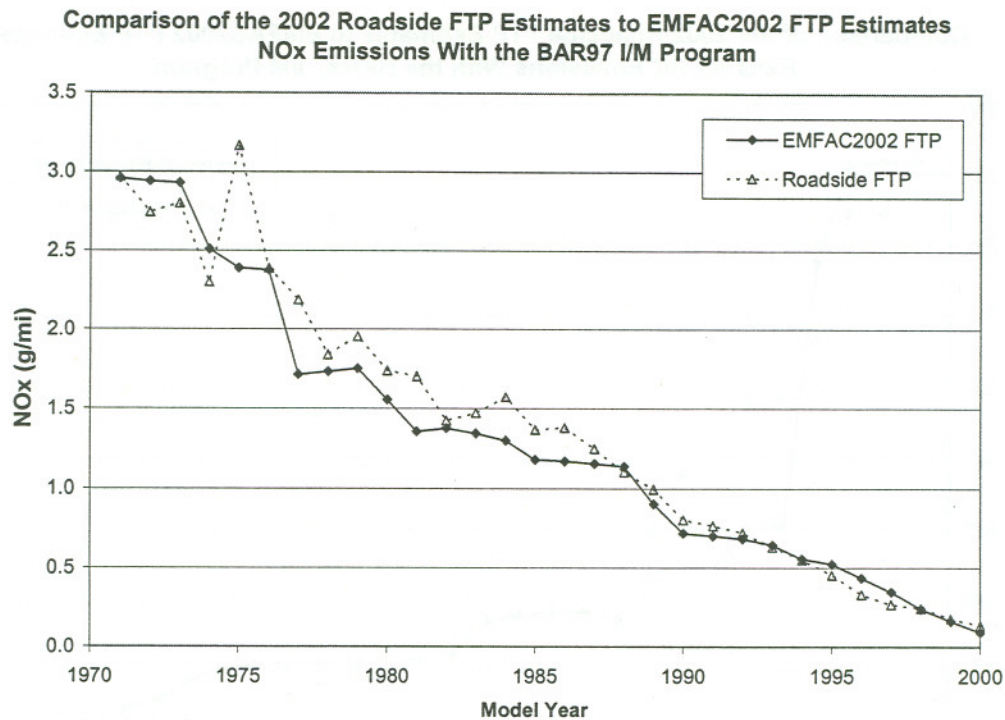


Figure 2.7



2.2 Impact of Exemption of 5 and 6 Year Old Vehicles

As amended by AB2637, Section 44011(a)(4)(B) of the California Health and Safety Code provides for newer vehicles to be exempted from the state's Inspection and Maintenance (I/M) program for an additional two years (for the first six years instead of just four years) beginning January 1, 2004. However, this extension of the model year exemption was contingent upon a finding by the Air Resources Board that it will not prohibit the state from meeting State Implementation Plan (SIP) commitments.

Analysis of currently available data from several different sources was performed to estimate the loss in emission benefits expected to occur as a result of excepting additional new vehicle model years; both exhaust and evaporative emissions impacts were considered in the evaluation. The analysis focused on those areas of the state with Enhanced I/M ASM testing already in place or expected by January 2004 (and thus includes the San Francisco Bay Area).

The results of this analysis are provided in a separate technical support document, dated April 2, 2003, that was developed in support of the Air Resources Board's finding that in order for California to meet its SIP obligations, it would be necessary to exclude Enhanced Smog Check areas from the six-year exemption. The Board also found that exempting five- and six-year old vehicles in Basic Smog Check areas located in severe or extreme federal ozone non-attainment areas from biennial inspections would interfere

with the State's ability to meet its SIP commitments. A copy of the separate technical support document is available at <http://www.arb.ca.gov/msprog/inusecom/tsdver5.doc>.

2.2.1 Predicting the Benefit from Exemption of 5/6 Year Old Vehicles

As a first phase in developing a LEP model, the vehicle lookup table (VLT) row identification (ID) number and overall test result were extracted from ASM test records collected during the period of July 1, 2002 to March 31, 2003. The results were used to determine average failure rate by VLT row ID. This phase included the following analysis steps:

1. The total number of each type of overall result (possible entries are P for pass, F for fail, G for gross polluter, or T for tampered) were counted for each VLT row ID.
2. The number of passes (P), fails (F+G+T), total tests (P+F+G+T), and failure rate $[(F+G+T)/(P+F+G+T)]$ were computed for each VLT row ID.
3. Any VLT row ID with less than 50 total tests was removed from the dataset.
4. All default VLT row IDs (i.e., those that pertain to non-specific test vehicles) were removed from the dataset.

The next phase of the analysis involved the development of a conversion table that would allow the first 10 characters of the vehicle's Vehicle Identification Number (VIN) to be matched to a specific VLT row ID. Using BAR97 data from January 1, 2000 to March 31, 2003, the following analysis steps were performed:

1. VIN and VLT Row ID were extracted from each test record.
2. Records with default VLT row IDs were removed from the dataset.
3. A Vin10 field was added and populated using the first 10 digits of the VIN (VIN stem).
4. The data were grouped by Vin10 and VLT row ID.
5. Records in which more than one VLT row ID was associated with a single Vin10 entry were removed from the dataset, resulting in a completed Vin10-to-VLT Row ID conversion table.

The results of the above analysis phases were then used to develop estimates of the projected loss in HC plus NOx emissions reductions that would occur if an LEP were implemented to "clean screen" five and six year old vehicles. This third phase was done using the following steps:

1. Vehicle records were analyzed to identify the vehicles due for Smog Check inspection in February 2003. This was done by extracting VID records from the DMV_Vehicles table that had a Smog Check inspection due date (SMOG_INSP_DUE_DT) and a DMV registration expiration date (DMV_EXP_DT) equal to this month.
2. The Vin10 entries from the DMV_Vehicles table were matched to the Vin10-to-VLT row ID conversion table created in Phase 2 above. This allowed the VLT row ID for each vehicle identified under Phase 3, Step 1 to be determined from the VIN.
3. The VLT row ID identified for each subject vehicle under Phase 3, Step 2 was matched to the VLT row ID and VLT failure rate dataset developed previously in Phase 1, Step 2.
4. All vehicles from Phase 3, Step 1 were sorted in descending order based on the VLT failure rate. The vehicles were then grouped and counted by VLT row.
5. The following equation was used to compute the percent contribution of the vehicles in each VLT row to the overall BAR97 failure rate for the dataset:

$$\text{Percent of Failures} = \frac{N_{VLTRow} \times FR_{VLTRow}}{\sum (N_{VLTRow} \times FR_{VLTRow})} \quad (1)$$

where: N_{VLTRow} = number of vehicles in an individual VLT row
 FR_{VLTRow} = failure rate of the individual VLT row

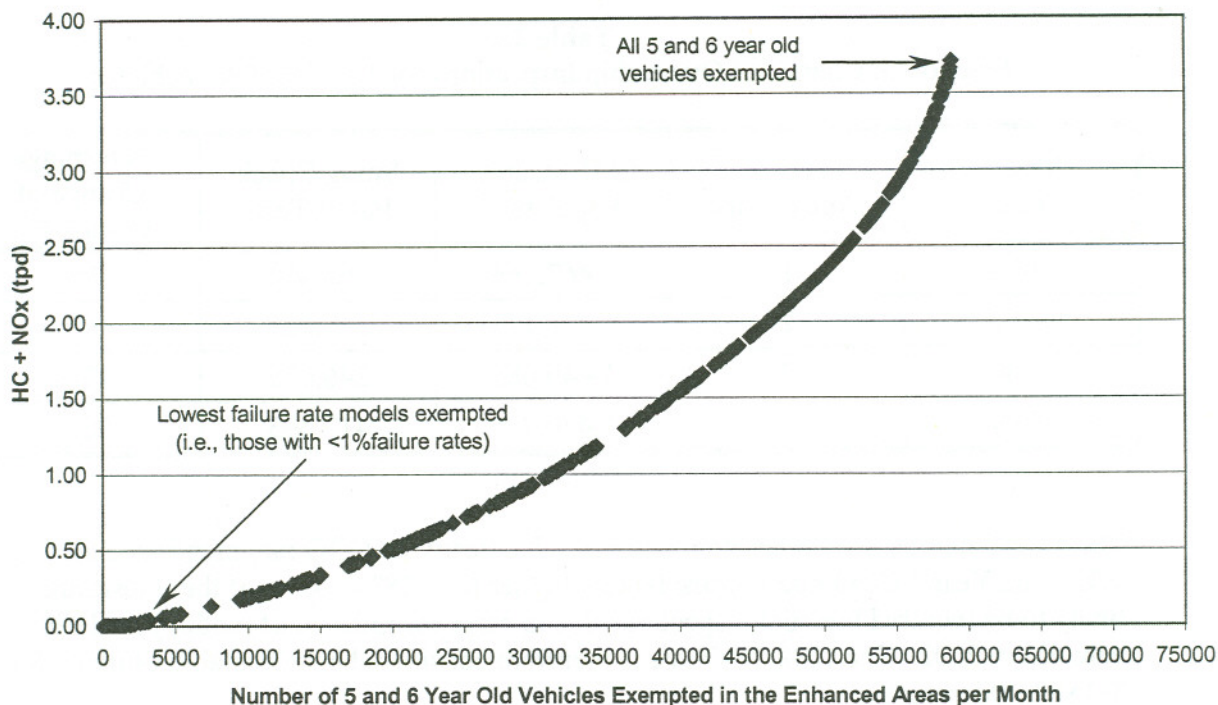
6. The percent of failures computed for individual VLT rows were then multiplied by a factor of 3.71* to estimate the tons per day (tpd) of ROG+NOx emissions reductions that would be lost if the vehicles in those rows were exempted from biennial Smog Check inspection requirements.

Results - The above methodology was used by BAR to estimate the loss in emission reductions that could occur in 2005 if five and six year old vehicles are exempted from biennial inspections under a LEP scenario in which the cleanest vehicles are exempted first. Figure 2.8 shows the cumulative impact in 2005 of exempting various numbers of these vehicles.

* As shown in Table 1.5 of <http://www.arb.ca.gov/msprog/inusecom/tsdver5.doc>, 3.71 tpd is the total loss in ROG+NOx benefits that is projected to occur in 2005 if all five and six year old vehicles are exempted from biennial inspections. This approach implicitly assumes that there would be a proportional loss in benefits from each vehicle exempted under a LEP aimed at the five and six year old vehicles.

Figure 2.8

Projected Loss in Emission Reductions from Exempting 5 and 6 Year Old Vehicles
(Based on February 2003 Enhanced Area Vehicle Renewals)



Reliance on Existing Test Data - Implicit in the above calculation of benefits is that test results from five and six year old vehicles would be available to determine average failure rate by VLT row. However, if these vehicles are being clean screened and not tested, no data would be available for them. The intended approach to this issue is to use change of ownership (COO) inspection data from four year old vehicles* to develop the needed failure rate information that would allow low emitting five and six year old vehicles to be clean screened.

The COO inspection rate has historically been assumed to be 17% on a fleetwide basis. For this analysis, the fraction of newer vehicles that received a COO inspection each year was determined on a model year specific basis to assess the feasibility of using test results from three and four year old vehicles to construct the LEP model for five and six year old vehicles. This was done by comparing the number of initial tests (by model year) found in BAR's "Executive Summary Report" for calendar year 2002 to estimated vehicle population (by model year) from EMFAC2002. Because the newer model year vehicles receiving inspections are not yet subject to a periodic biennial inspection, it was

* This may be supplemented with COO data from three year old vehicles to provide sufficient representative results on a VLT row-specific basis. If the three and four year old data are combined, the three year old results will be "aged" to put all failure rates on a common age basis.

assumed that these vehicles were undergoing a COO inspection. A summary of the results is shown in Table 2.6.

Table 2.6
Fraction of Change of Ownership Inspections for 1-4 Year Old Vehicles

Model Year	Vehicle Age (Year)	EMFAC2002 Population	Smog Check Initial Tests	Percentage Change of Ownership
2002	1	1,467,166	104,434	7%
2001	2	1,447,171	220,950	15%
2000	3	1,440,685	246,075	17%
1999	4	1,470,906	417,603	28%

The Year 3 numbers are consistent with the 17% fleetwide COO rate mentioned above. While the Year 4 COO rate is considerably higher (i.e., 28%), some of these tests are likely to be required biennial inspections due to early compliance of model year 1999 vehicles in 2002. The 17% COO rate is therefore considered an acceptable estimate for 3-4 year old vehicles.

As detailed elsewhere in the Report to the Legislature, it is recommended that two year old and newer vehicles be exempted from COO inspections. It is emphasized that clean screening five and six year old vehicles will be dependent on continuing the COO inspections on three and four year old vehicles to provide a source of the data needed to populate the LEP model. While it might be possible to use test results from another I/M program to populate the model, an increasing number of programs are exempting the first four model years from inspection. This, coupled with concerns regarding the representativeness of non-California test data, means that continuing COO Smog Check inspections for three and four year old vehicles are a necessary component of any effort to clean screen five and six year old vehicles.

2.3 Evaluating Station Performance

This section discusses the methodology used to examine Smog Check station performance. Several statistical techniques are provided that compare the ability of Test-Only and Test-and-Repair stations to properly identify polluting vehicles. In addition, roadside data and Smog Check inspection data are used to evaluate the quality and durability of Smog Check repairs.

2.3.1 Station Ranking Analysis

The first method to evaluate station performance involved the ranking of test stations by their relative performance levels, using a methodology previously developed and used in the June 2000 Smog Check station performance report.² This approach ranks stations based on their actual failure rate compared with the expected failure rate. Smog Check test records (VID data) are used to calculate expected and reported failure rates. An individual station's expected failure rate is based on the average failure probability (Fprob) of the set of vehicles tested at the station. The difference between the actual and average failure rate is divided by the standard error of the average failure rate to determine the number of standard deviations between the actual and average failure probabilities.

$$N_{\sigma} = (F_p - FR) / \text{Std Err} \quad (2)$$

Where: F_p = Average expected failure rate at a station
FR = Actual failure rate at a station
Std Err = Standard error of the expected failure rate at a station
 N_{σ} = Station performance ranking

N_{σ} is used to rank the stations. Stations ranked at the top report failure rates that exceed the average failure rates and thus have negative N_{σ} values. Stations ranked at the bottom report failure rates that are much lower than average failure rates and therefore have positive N_{σ} values.

For the current analysis, the station ranking was done using VID data collected from December 2000 through November 2001. Aborted tests, hands-on, and training mode tests (collectively referred to as invalid tests) were eliminated from the dataset. Vehicle-specific failure probabilities were assigned using the latest "Fprob" dataset available at the time of the analysis.

Only initial tests were considered in this ranking. To determine whether tests were the initial test for the inspection cycle, six months of data prior to December 2000 were examined. A test was considered an initial test if there was no other test of the vehicle occurring in the previous six months. Each vehicle could only be considered once in the analysis. For example, if a vehicle appeared once in December 2000, and again in November 2001, only the December event was included in the analysis.

Once the initial tests were identified and all invalid tests removed, the mean of the Fprobs, the standard error of the Fprob, and the failure rate were determined for each station. From this, the ranking metric, N_{σ} , was calculated using Equation (2). Stations having fewer than 30 initial inspections performed during the analysis period were excluded from the analysis.

Using the ranking metric, stations were grouped into quartiles. The top 25% of the stations, which were the 25% of stations with the lowest N_G score (these could be negative), were considered the “Best” stations, whereas the 25% of the stations with the highest N_G score were considered the “Worst” stations. The “Fprob” dataset was provided by ERG and includes Fprob values, vehicle model year, make, model, and engine displacement information decoded from the VIN using a contractor (Eastern Research Group or ERG) supplied VIN-decoder-based application.

Results –The current results were compared to those from the analysis performed for the 2000 station performance report. The top portion of Table 2.7 shows the results of the 2000 analysis. It used the older Fprobs, which were current at the time, and VID data collected in 1999. The bottom portion of the table shows the updated station performance results that were developed in the current analysis.

Table 1.7
Percent of Stations by Rank Using Smog Check Inspection Records
(Based on Data Collected in 1999 and 2001)

1999 Evaluation				
Ranking (Percent)	Enhanced Test-Only		Enhanced Test and Repair	
	Percent of Stations	Percent of Vehicles Inspected	Percent of Stations	Percent of Vehicles Inspected
0 - 25 (Best)	59.9	12.8	21.2	19.3
25 - 50	21.5	3.6	25.4	17.3
50 - 75	12.3	2.5	26.4	18.1
75 - 100 (Worst)	6.3	1.4	27.0	25.0
All	100.0	20.2	100.0	79.8
2001 Evaluation				
Ranking (Percent)	Test-Only		Test and Repair	
	Percent of Stations	Percent of Vehicles Inspected	Percent of Stations	Percent of Vehicles Inspected
0 - 25 (Best)	58.1	19.2	19.8	16.2
25 - 50	18.9	4.5	26.1	12.9
50 - 75	12.4	3.0	27.1	14.9
75 - 100 (Worst)	10.6	3.6	26.9	25.7
All	100.0	30.4	100.0	69.6

2.3.2 Repeat Emissions Analysis

The second method used to identify potential improper or fraudulent station performance involved repeat emissions analysis. This approach involved analyzing the degree of similar emissions scores among all test results recorded by each individual emissions analyzer to identify instances of suspected “clean piping” (i.e., fraudulently measuring emissions from a clean vehicle during the testing of a different vehicle in order to falsely

pass an otherwise failing vehicle). Statistical cluster analysis was used to identify similar emissions scores and group them for further analysis.

Cluster analysis works by organizing information about variables so that relatively homogenous groups, or “clusters,” can be formed. To visualize how cluster analysis works, consider a two-dimensional scatter plot. Cluster analysis will attempt to identify a locus of points by “drawing” circles on the plot in such a way as to fit the maximum number of points within each circle. On a three-dimensional plot, the circle becomes a sphere in order to fit data along all three dimensions. While it becomes increasingly difficult to visualize how this process works as the number of variables increases, cluster analysis can cluster items along many different dimensions.

All four emissions constituents—HC, CO, NO_x, and CO₂—were considered relative to each other in the cluster analysis of VID data. Readings from each of the four constituents had to be similar in order for inspection results to be considered similar. The likelihood of this occurring randomly at a much higher frequency at certain stations relative to the overall network average is very low. A high incidence of test results that show similar emissions for all four constituents is therefore considered strong evidence of potential clean piping.

Due to the intensive computing required by the repeat emissions analysis, only two months of VID data were used, June and July 2001. From these data, initial tests were determined using the criteria described above under the station ranking analysis. Since the analysis was focused on test results from June-July 2001, data from the period of December 2000 through May 2001 were used for the initial test determination. All invalid (aborted, hands-on, and training mode) tests were also eliminated from the dataset.

Having identified initial inspections, the next step was to attempt to remove the cleanest vehicles that would tend to produce similar emission results because the emissions would all be near zero, or, in the case of CO₂, near 14.7%. For this reason, 1996 and newer vehicles were eliminated, as were vehicles where HC, CO, and NO_x were below 10 ppm, 0.2%, and 10 ppm, respectively.

Using the resulting dataset, the test results were grouped into clusters by emission scores using identically sized clusters. In other words, the size of the cluster was constrained by the relative differences in emission scores rather than the number of inspections within a cluster. As previously mentioned, a cluster contains vehicle inspection results where the emissions for each of the four constituents are similar.

The number of vehicles in a cluster could be set to any amount greater than or equal to one. For this analysis, clusters were considered only if they contained at least four inspections and the total number of inspections within a cluster was greater than 4% of the total number of inspections performed by the station. The latter criterion ensured that stations performing large numbers of inspections, which would naturally have higher

numbers of repeat emissions based simply on random variation, would not be improperly identified.

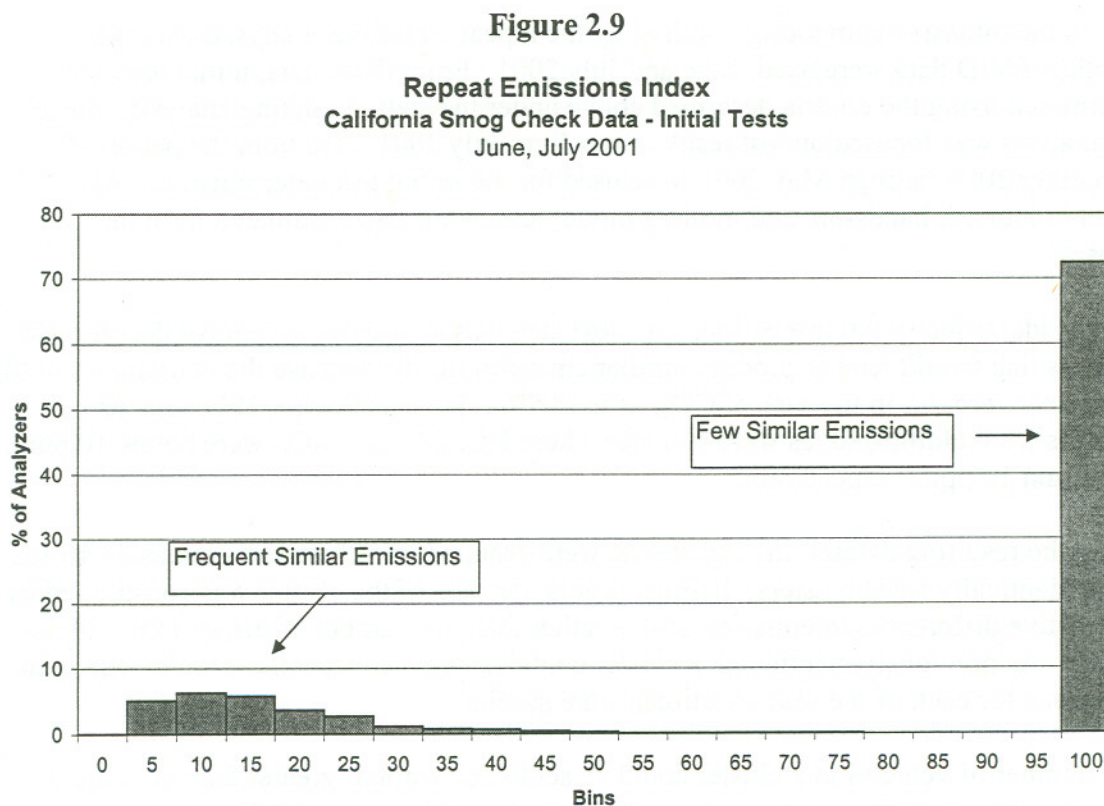
Once the number of significant clusters for each station was determined, index scores were developed to rank the stations from zero to one hundred based upon the number of clusters found according to the following formula.

$$\text{Station Index Score} = [(\text{Max} - \text{Current}) / (\text{Max} - \text{Min})] * 100 \quad (3)$$

Where: Current = Number of clusters for a given station
Max = Number of clusters for worst performing station
Min = Number of Clusters for best performing station

Results – Based on Equation (3), zero represents the station with the greatest number of clusters while 100 represents stations with the fewest number of clusters (zero).

Figure 2.9 shows the distribution of index scores resulting from this analysis.



The figure shows that, as expected, most (nearly 75%) Smog Check stations report relatively few similar emissions scores, as evidenced by their index scores of 100.

However, the incidence of near-zero index scores is a strong indication that these stations may be engaging in fraudulent clean piping activities.

Table 2.8 compares repeat emissions results to the ratio of the actual/average station failure rate for three performance groupings: those “worst performers” with index scores of less than 15, medium performers that have index scores of 15 to less than 100, and best performers that have index scores of 100. Within each of these groups, actual/average failure rate ratios are shown for Test-and-Repair and Test-Only stations, as well as the combined total of all Smog Check stations.

Table 2.8
Repeat Emissions Index Score versus Actual/Average Failure Rate*

Repeat Emissions Index Rate	Station Type	Fail Rate/ Average Fail Rate	Percent of Station Type
Less than 15 (Worst)	Test & Repair	0.76	20.4
	Test-Only	1.20	1.3
	Total	0.81	
Greater than or equal to 15 and less than 100	Test & Repair	0.88	11.6
	Test-Only	1.16	3.0
	Total	0.88	
100 (Best)	Test & Repair	0.96	68.0
	Test-Only	1.18	95.7
	Total	1.05	
Total		0.99	

*Average Actual Failure Rate / Average Failure Probability

The results shown in the table support the validity of using repeat emissions analysis to identify possible problem stations. Test-Only stations clearly show the best results based on repeat emissions index scores. The distribution of repeat emissions performance among the Test-Only and Test-and-Repair station categories is summarized in Table 2.9.

Table 2.9
Summary of Repeat Emissions Analysis Results

Repeat Emissions Index Rate	Enhanced Test-Only	Enhanced Test and Repair
	Percent of Stations	Percent of Stations
100 (Best)	95.7	66.4
Greater or equal to 15 and less than 100	3.0	12.3
Less than 15 (Worst)	1.3	21.3
All	100.0	100.0

There is also good correlation between the repeat emissions rankings and the ratio of actual to average failure rates, particularly for the Test-and-Repair stations. As shown in Table 2.8 the best, middle, and worst Test-and-Repair stations have respective actual/average failure ratios of 0.96, 0.88, and 0.76. That is, the best performers have the highest average failure rate, while the worst performers have a lower than average failure rate.

While insufficient roadside data are available to further validate the repeat emissions results, the strong correlation between these index scores and station type suggests that the indicator is doing a good job of identifying questionable station performance.

2.3.3 Roadside Data Analysis

The third method used to examine Smog Check station performance involved analyzing test data obtained from the roadside inspection program and comparing the results of that analysis to VID data from official Smog Checks. For this analysis, test results from the roadside dataset were matched with the chronologically nearest test from the VID database for each vehicle.

The roadside data utilized in this analysis were collected from January 2000 to October 2002. The roadside results were separated into two groups. The before-Smog Check group included those vehicles for which roadside test results were available from within one year prior to the Smog Check inspection date. After-Smog Check vehicles included those for which roadside results were available from within one year after the Smog Check inspection date. Failure rates were computed for both groups of vehicles and emissions results were computed for the vehicles included in the after-Smog Check group.

Data within each vehicle sample used in the analysis were weighted to the vehicle model year travel fractions contained in EMFAC2002 to maximize consistency between estimated mass emissions results and projections from the model. The EMFAC2002 travel fractions, split into four model year groupings, are shown in Table 2.10. 1996 and newer models were omitted from the travel fractions and subsequent analysis since there were insufficient roadside data in this model year grouping to produce statistically valid results.

Table 2.10
EMFAC2002 Model Year Travel Fractions
 (Model Years 1974 through 1995)

Model Year Group	Weighting
1974-1979	0.033
1980-1986	0.165
1987-1991	0.383
1992-1995	0.419
Total	1.000

Roadside and VID results were then compared using tailpipe (ASM) failure rates and average emissions scores. All ASM emissions scores were converted to an FTP basis for this analysis, using the ASM-to-FTP correlation equations presented in Appendix A, which were described previously.

Average Roadside Emissions Results – Table 2.11 shows the difference between the average emissions of vehicles that pass their initial smog inspection and those that must be repaired to pass the inspection. As noted above, these results were obtained by applying the EMFAC2002-based model year travel fractions in Table 2.10 to the raw roadside test data.

Table 2.11
Average Emission Scores For Roadside Vehicles
Following Their Smog Check Inspection*
 (Model Years 1974-1995)

Smog Check Result	FTP HC (g/mi)	FTP CO (g/mi)	FTP NOx (g/mi)
Passing After Initial Failure	1.09	13.53	1.16
Passing Initial	0.76	9.93	0.88
Difference	0.33	3.60	0.28

* Based on roadside vehicles tested between January 2000 and October 2002.

Roadside Versus VID Tailpipe Failure Rates – Roadside tailpipe failure rates were examined relative to recorded VID failure rates in order to gain a better understanding of

how failure rates achieved at Smog Check stations compared with those observed in the roadside data. Unfortunately, due to a number of factors such as deterioration in emissions performance over time, pre-inspection repairs, and inconsistent test results, it is difficult to determine what the expected failure rate should have been.

Presumably, roadside tests results occurring before an initial Smog Check would have similar failure rates to the actual Smog Check results. The main source of differences, aside from fraud, would be either pre-inspection repairs that would occur after the roadside inspection, or vehicle emissions deterioration that might occur between the time when the roadside test occurred and the time of the Smog Check inspection.

Similarly, roadside tests occurring after a vehicle passed its Smog Check should be relatively similar to the Smog Check results. Aside from fraud, the principle source of discrepancy would be emissions deterioration occurring after the vehicle passed its inspection.

Overall Smog Check versus roadside failure rates were computed for the 1974-1999 model year test fleet. To better reflect the actual Smog Check test fleet, results were corrected to the model year distribution in the VID database from December 2000 through November 2001 (in lieu of the EMFAC2002 travel fractions). Table 2.12 shows the resulting model year weighting factors, split into five model year groupings, that were used.

Table 2.12
Model Year Weighting Factors from California VID Data, 12/00 through 11/01
(Model Years 1974 through 1999)

Model Year Group	Weighting
1974-1979	0.033
1980-1986	0.153
1987-1991	0.303
1992-1995	0.292
1996-1999	0.218
Total	1.000

* The individual values do not sum up to 1,000 due to rounding

Table 2.13 shows resulting Smog Check versus roadside failure rates for the 1974-1999 model year test fleet. Only records where the roadside test occurred within one year of the I/M test were considered in the analysis.

Table 2.13
Smog Check versus Roadside Tailpipe Failures for All 1974-1999 Model Year Vehicles*
(Roadside Results Within 1 Year of Smog Check Results)

	Count	Smog Check Failure Rate	Roadside Failure Rate
Roadside Before Smog Check	3521	14.1	18.0
Roadside After Smog Check	4661	0.0	15.1

* Results corrected to VID vehicle distribution for 12/2000 through 11/2001.

To be consistent with how pass/fail decisions are made during Smog Check inspections; the results shown in the table are based on the same fast-pass logic as programmed into the BAR97 test systems. This is important since the fast-pass test procedure essentially gives vehicles multiple chances to pass throughout the test (i.e., whenever consecutive 10-second average readings for HC, CO and NO are all below the applicable standards). Comparing full duration roadside results to Smog Check inspection results with fast pass enabled could therefore skew this comparison. To avoid this, second-by-second data from the roadside tests were analyzed to determine the failure rates with fast pass enabled.

The table clearly shows large disparities between the Smog Check and roadside failure rates. 15.1% of the vehicles that passed their Smog Check were found to fail a subsequent roadside tailpipe test that occurred within a year of the Smog Check. In addition, there was a failure rate difference of 3.9% (18.0%-14.1%) in vehicles failing a previous roadside test versus when they showed up for their Smog Check.

A potential key contributor to roadside failures among vehicles that had previously passed their Smog Check is in-use emissions deterioration; i.e., defects occur in these vehicles after their Smog Check that cause failing emissions scores at the roadside. Therefore, to better help understand the results shown in Table 2.13 the amount of time in days that transpired between the roadside and Smog Check inspections was analyzed. Presumably, the larger the amount of time that transpired between the tests, the greater the amount of vehicle emissions deterioration that may have occurred. Table 2.14 shows the average time in days between the roadside and Smog Check inspection for the test results used to calculate the failure rates subsequently shown in Table 2.15. Since roadside results had to fall within one year of the Smog Check inspection to be included in the dataset, it makes sense that the average time is in the ballpark of 180 days.

Table 2.14
Average Days between Roadside and Smog Check Inspection
For All 1974-1999 Model Year Vehicles*
(Roadside Results Within 1 Year of Smog Check Results)

	Roadside Before Smog Check	Roadside After Smog Inspection
Average Days	151	169

* Results corrected to VID vehicle distribution for 12/2000 through 11/2001.

However, the 3.9% decrease in failure rate seen between the pre-Smog Check roadside fast-pass results and the actual Smog Check results is directly counterintuitive to the theory that emissions deterioration is the cause of the disparity in the roadside and Smog Check results. While pre-inspection repairs could account for a portion of the difference between pre-Smog Check roadside inspection and the actual Smog Check results, the large disparity in the post-Smog Check roadside inspection and actual Smog Check results appears to reflect a degree of fraudulent testing. In fact, the difference in roadside failure rates between the before and after Smog Check tests is only 2.9%.

To provide additional insight into this issue, the roadside versus Smog Check data were further analyzed by looking strictly at the vehicles that failed their initial I/M inspection from the "Before" sample and those that passed after failing their initial test from the "After" sample. This analysis step thus focused on those vehicles that failed Smog Check and were presumably repaired before being issued an inspection certificate.

Table 2.15 shows the results of this analysis. For the pre-Smog Check group shown in the table, of the vehicles that eventually failed their initial Smog Check, only 69.2% failed their roadside inspection. While this disparity may seem large, it is possible because all of these vehicles supposedly passed their previous Smog Check. Those that fail the subsequent Smog Check might be expected to deteriorate in a linear fashion. As a result, almost three-quarters of the failing vehicles would fail at three-quarters of the way through their biennial inspection cycle.

Table 2.15
Smog Check versus Roadside Tailpipe Failures for Initially Failing
1974-1999 Model Year Vehicles*
(Roadside Results Within 1 Year of Smog Check Results)

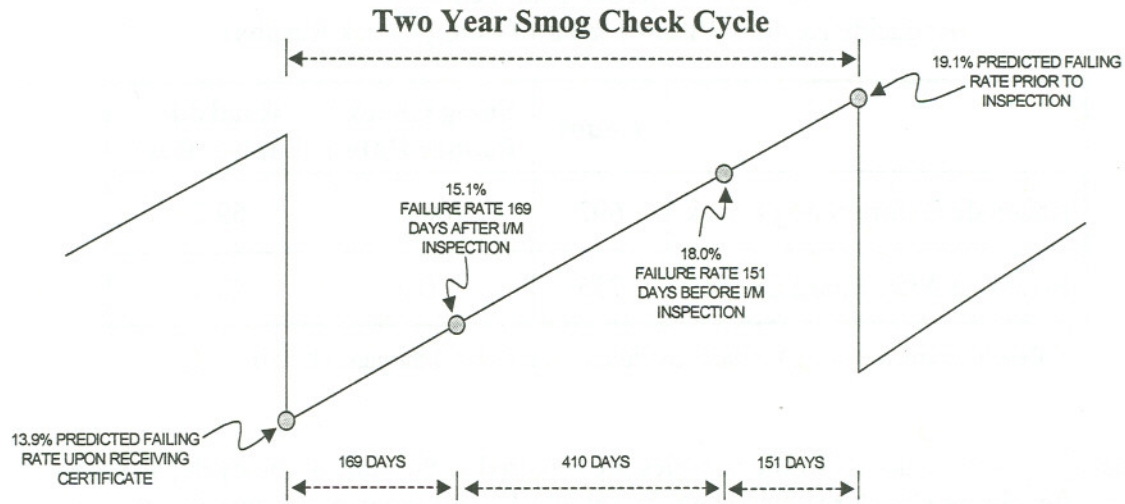
	Count	Smog Check Failure Rate	Roadside Failure Rate
Roadside Before Smog Check	692	100.0	69.2
Roadside After Smog Check	735	0.0	40.4

* Results corrected to VID vehicle distribution for 12/2000 through 11/2001.

In reality, however, not all of the vehicles are repaired at the start of the cycle, as shown by the after-Smog Check results shown in Table 2.15. Of the vehicles that failed their Smog Check and were supposedly repaired, 40.4% failed a roadside inspection that was subsequently conducted within six months on average of the Smog Check. This failure rate appears much higher than can be accounted for by vehicle deterioration, even if it is assumed that repaired vehicles are likely to have significantly higher deterioration rates than passing vehicles.

While unknown factors related to elements such as the actual rate of vehicle emissions deterioration, the amount of pre-inspection repairs that are occurring, and the degree of test fraud among inspection stations remain, an effort was made to estimate what the failure rate should have been at the time of the Smog Check inspection. For this effort, the vehicle deterioration rate was assumed to be linear. Based on this assumption, it is possible to extrapolate the "actual" overall Smog Check failure rate using the roadside failure rates and the amount of time (relative to the biennial inspection cycle) transpiring between the roadside and the I/M test. Figure 2.10 shows the relationship between failure rate and time since/before Smog Check based on the roadside test results. The roadside failure rates (15.1% and 18.0%) and the times between the roadside tests and Smog Check inspections (169 and 151 days) shown in the figure are taken directly from the results contained in Tables 2.13 and 2.14.

Figure 2.10
Variation in Failure Rates over Smog Check Cycle



To estimate the before and after Smog Check failure rate at the time of the Smog Check, a linear extrapolation of the roadside data was performed. Using the observed roadside failure rates (with fast pass enabled) shown in Figure 2.10, the rate of emissions deterioration per day was calculated as follows:

$$\text{Change in Failure Rate / Day} = (18.0 - 15.1) / 410 = 0.00707 \quad (4)$$

The failure rate for vehicles about to get a Smog Check can then be calculated as follows:

$$18.0 + (0.00707 \times 151) = 19.1\% \quad (5)$$

Similarly, the failure rate immediately after Smog Check can be calculated as follows:

$$15.1 - (0.00707 \times 169) = 13.9\% \quad (6)$$

The results of Equations (5) and (6) are respectively shown in Figure 2.10 as predicted failing rates prior to initial inspection in an I/M cycle and upon receiving an I/M certificate at the end of the previous biennial I/M cycle. If the relationship between failure rate and time since Smog Check is truly linear, this could indicate falsified test results. However, it is possible that more of the vehicles actually pass Smog Check after receiving ineffective or partial repairs and then deteriorate rapidly. Regardless of whether the deterioration is linear or non-linear, this analysis suggests that a portion of the vehicles that fail Smog Check are not getting effectively repaired.

2.4 Estimating the Emission Benefits from the Inspection of Smoking Vehicles

Based on testing by Southwest Research Institute (SWRI)⁴, smoking vehicles have average particulate emission rates of 0.27 g/mi during the warmed up portion of the standard exhaust emissions test. In contrast, vehicles in proper repair have particulate emission rates at least 90% lower. Based on the particulate emissions measured in the SWRI study, the benefits of repairing each smoking vehicle would be at least 0.24 g/mi. A 1999 study for the South Coast Air Quality Management District (SCAQMD)⁵ indicated that a sample of 18 smoking gasoline vehicles and 5 smoking Diesel vehicles had a particulate emissions rate of 0.35 g/mi on the IM240 test (Diesel and gasoline vehicles had almost exactly the same level of particulate emissions). The study noted that particulate emissions from non-smoking vehicles on the IM240 cycle have been reported to be 0.051 to 0.094 g/mi. Using the high end of this range, the difference in particulate emissions between smoking and non-smoking vehicles is 0.26 g/mi.

The visual survey of on-road vehicles included in the SCAQMD study found that between 1.1 and 1.8% of the light-duty fleet emits some visible smoke, with smoking vehicles primarily consisting of both gasoline and Diesel vehicles that are 8-18 years old. Of the smoking vehicles, 73% were determined to be gasoline-fueled. Based on the 2002 edition of Ward's Motor Vehicle Facts and Figures⁶ total passenger car and light truck registrations in California for calendar year 2000 were 26.2 million; 1.1% of this total is 289,000 smoking vehicles. If gasoline vehicles account for 73% of the smoking vehicles, the total number of gasoline-fueled smoking vehicles is 211,000.

Using a conservative estimate that the Smog Check program could cause the repair of 200,000 smoking gasoline-fueled light-duty vehicles driving 30 miles per day, the potential benefits are statewide reductions in particulate emissions of 1.65 tons per day (0.25 g/mi reduction times 30 mi/day times 200,000 vehicles). The repair of smoking vehicles would also be expected to provide some additional reductions in HC, CO, and NOx emissions.

2.5 References

1. Evaluation of California's Enhanced Vehicle Inspection and Maintenance Program (Smog Check II)," Final Report, Air Resources Board, July 12, 2000.
2. "Models for Estimating California Fleet FTP Emissions from ASM Measurements," Final Report, prepared by Eastern Research Group for the Bureau of Automotive Repair, December 17, 1997.
3. "Smog Check Station Performance Analysis (Based on Roadside Test Results)," prepared by dKC and Eastern Research Group, for California Bureau of Automotive Repair, Engineering and Research Branch, June 27, 2000.
4. "Measurement of Primary Exhaust Particulate Matter Emissions From Light-Duty Motor Vehicles," November 1998.{ XE "\"Measurement of Primary Exhaust Particulate Matter Emissions From Light-Duty Motor Vehicles,\"" November 1998." }
5. Durbin, T.D., Smith, M.R., Norbeck, J.M. and Truex, T.J., "Population Density, Particulate Emission Characterization, and Impact on the Particulate Inventory of Smoking Vehicles in the South Coast Air Quality Management District," J. Air & Waste Management Assoc., 1999, 49(1), 28-38.{ XE "Durbin, T.D., Smith, M.R., Norbeck, J.M. and Truex, T.J., \"Population Density, Particulate Emission Characterization, and Impact on the Particulate Inventory of Smoking Vehicles in the South Coast Air Quality Management District,\" J. Air & Waste Management Assoc., 1999, 49(1), 28-38" }
6. Ward's Motor Vehicle Facts & Figures 2002, Ward's Communications.{ XE "Ward's Motor Vehicle Facts & Figures 2002, Ward's Communications" }

Appendix 2A

Revised ASM-FTP Correlation Equations

As noted in the text of this report, revised correlation equations were developed that predict FTP scores from ASM results. The general methodology followed that developed for the July 2000 evaluation of the Smog Check Program.* One difference, however, is that two sets of equations were developed for the current effort – one based on pre-1990 model year vehicles and the other based on 1990 and newer model year vehicles. The correlations are summarized below, followed by the regression statistics for these correlations.

Pre-1990 Model Year Correlation Equations

$$\begin{aligned} \text{FTP_HC} = & 1.2648 * \exp(- 4.67052 \\ & + 0.46382 * \text{hc_term} \\ & + 0.09452 * \text{co_term} \\ & + 0.03577 * \text{no_term} \\ & + 0.57829 * \text{wt_term} \\ & - 0.06326 * \text{my_term} \\ & + 0.20932 * \text{trk}) \end{aligned}$$

$$\begin{aligned} \text{FTP_CO} = & 1.2281 * \exp(- 2.65939 \\ & + 0.08030 * \text{hc_term} \\ & + 0.32408 * \text{co_term} \\ & + 0.03324 * \text{co_term}^2 \\ & + 0.05589 * \text{no_term} \\ & + 0.61969 * \text{wt_term} \\ & - 0.05339 * \text{my_term} \\ & + 0.31869 * \text{trk}) \end{aligned}$$

$$\begin{aligned} \text{FTP_NOX} = & 1.0810 * \exp(- 5.73623 \\ & + 0.06145 * \text{hc_term} \\ & - 0.02089 * \text{co_term}^2 \\ & + 0.44703 * \text{no_term} \\ & + 0.04710 * \text{no_term}^2 \\ & + 0.72928 * \text{wt_term} \\ & - 0.02559 * \text{my_term} \\ & - 0.00109 * \text{my_term}^2 \\ & + 0.10580 * \text{trk}) \end{aligned}$$

* "Models for Estimating California Fleet FTP Emissions from ASM Measurements," Final Report, prepared by Eastern Research Group for the Bureau of Automotive Repair, December 17, 1999.

where:

```
hc_term = ln( (ASM1_HC*ASM2_HC)^.5 ) - 3.72989
co_term = ln( (ASM1_CO*ASM2_CO)^.5 ) + 2.07246
no_term = ln( (ASM1_NO*ASM2_NO)^.5 ) - 5.83534
```

```
MY_Term = model_year - 1982.71
```

```
wt_term = ln( vehicle_weight )
```

```
TRK = 1 if a light-duty truck
```

```
TRK = 0 if a passenger car
```

1990 and Newer Model Year Correlation Equations

```
FTP_HC = 1.1754 * exp( - 6.32723
                        + 0.24549 * hc_term
                        + 0.09376 * hc_term**2
                        + 0.06653 * no_term
                        + 0.01206 * no_term**2
                        + 0.56581 * wt_term
                        - 0.10438 * my_term
                        - 0.00564 * my_term**2
                        + 0.24477 * trk) ;
```

```
FTP_CO = 1.2055 * exp( 0.90704
                        + 0.04418 * hc_term**2
                        + 0.17796 * co_term
                        + 0.08789 * no_term
                        + 0.01483 * no_term**2
                        - 0.12753 * my_term
                        - 0.00681 * my_term**2
                        + 0.37580 * trk) ;
```

```
FTP_NOX = 1.1056 * exp( - 6.51660
                        + 0.25586 * no_term
                        + 0.04326 * no_term**2
                        + 0.65599 * wt_term
                        - 0.09092 * my_term
                        - 0.00998 * my_term**2
                        + 0.24958 * trk)
```

where:

```
hc_term = ln (ASM1_HC*ASM2_HC)^.5 ) - 2.32393 ;
co_term = ln (ASM1_CO*ASM2_CO)^.5 ) + 3.45963 ;
no_term = ln (ASM1_NO*ASM2_NO)^.5 ) - 3.71310 ;
```

MY_Term = model_year - 1993.69;
 wt_term = ln(vehicle_weight)

TRK = 1 if a light-duty truck
 TRK = 0 if a passenger car

For cases in which the HC or NO ASM scores are zero, they are set to 1 ppm; for cases in which the CO ASM score is zero, it is set to 0.01%.

Pre-1990 Model Year Regression Statistics

The REG Procedure
 Model: MODEL1
 Dependent Variable: ln_HC

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	1093.54025	182.25671	577.41	<.0001
Error	1297	409.39250	0.31565		
Corrected Total	1303	1502.93275			

Root MSE	0.56182	R-Square	0.7276
Dependent Mean	0.06770	Adj R-Sq	0.7263
Coeff Var	829.89853		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > t
Intercept	1	-4.67052	0.65373	-7.14	<.0001
HC_Term	1	0.46382	0.01970	23.54	<.0001
CO_Term	1	0.09452	0.01306	7.24	<.0001
NO_Term	1	0.03577	0.01356	2.64	0.0085
Wt_Term	1	0.57829	0.08111	7.13	<.0001
MY_Term	1	-0.06326	0.00347	-18.24	<.0001
TRK	1	0.20932	0.03794	5.52	<.0001

Pre-1990 MY Vehicles
Humidity Corrected NOx Values

The REG Procedure
Model: MODEL2
Dependent Variable: ln_CO

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	970.89596	138.69942	304.94	<.0001
Error	1296	589.48099	0.45485		
Corrected Total	1303	1560.37696			

Root MSE	0.67442	R-Square	0.6222
Dependent Mean	2.53978	Adj R-Sq	0.6202
Coeff Var	26.55439		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > t
Intercept	1	-2.65939	0.78778	-3.38	0.0008
HC_Term	1	0.08030	0.02385	3.37	0.0008
CO_Term	1	0.32408	0.01576	20.57	<.0001
CO_Term2	1	0.03324	0.00581	5.72	<.0001
NO_Term	1	0.05589	0.01641	3.41	0.0007
Wt_Term	1	0.61969	0.09759	6.35	<.0001
MY_Term	1	-0.05339	0.00418	-12.77	<.0001
TRK	1	0.31869	0.04566	6.98	<.0001

Pre-1990 MY Vehicles
Humidity Corrected NOx Values

The REG Procedure
Model: MODEL3
Dependent Variable: ln_NOx

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	524.77234	65.59654	332.12	<.0001
Error	1295	255.77379	0.19751		
Corrected Total	1303	780.54613			

Root MSE	0.44442	R-Square	0.6723
Dependent Mean	0.18766	Adj R-Sq	0.6703
Coeff Var	236.81646		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > t
Intercept	1	-5.73623	0.50376	-11.39	<.0001
HC_Term	1	0.06145	0.01209	5.08	<.0001
CO_Term2	1	-0.02089	0.00382	-5.47	<.0001
NO_Term	1	0.44703	0.01235	36.18	<.0001
NO_Term2	1	0.04710	0.00452	10.43	<.0001
Wt_Term	1	0.72928	0.06227	11.71	<.0001
MY_Term	1	-0.02559	0.00343	-7.46	<.0001
MY_Term2	1	-0.00109	0.00036841	-2.96	0.0031
TRK	1	0.10580	0.03001	3.53	0.0004

1990 and Newer Model Year Regression Statistics

1990+ MY Vehicles
Humidity Corrected NOx Values

The REG Procedure
Model: MODEL1
Dependent Variable: ln_HC

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	281.90354	35.23794	167.72	<.0001
Error	621	130.46828	0.21009		
Corrected Total	629	412.37182			

Root MSE	0.45836	R-Square	0.6836
Dependent Mean	-1.49075	Adj R-Sq	0.6795
Coeff Var	-30.74692		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > t
Intercept	1	-6.32723	1.01565	-6.23	<.0001
HC_Term	1	0.24549	0.01782	13.77	<.0001
HC_Term2	1	0.09376	0.00876	10.70	<.0001
NO_Term	1	0.06653	0.01206	5.52	<.0001
NO_Term2	1	0.01206	0.00494	2.44	0.0150
Wt_Term	1	0.56581	0.12551	4.51	<.0001
MY_Term	1	-0.10438	0.00835	-12.50	<.0001
MY_Term2	1	-0.00564	0.00221	-2.55	0.0110
TRK	1	0.24477	0.04993	4.90	<.0001

1990+ MY Vehicles
Humidity Corrected NOx Values

The REG Procedure
Model: MODEL2
Dependent Variable: ln_CO

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	279.65432	39.95062	135.81	<.0001
Error	622	182.96667	0.29416		
Corrected Total	629	462.62098			

Root MSE	0.54236	R-Square	0.6045
Dependent Mean	1.09071	Adj R-Sq	0.6000
Coeff Var	49.72596		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > t
Intercept	1	0.90704	0.03971	22.84	<.0001
HC_Term2	1	0.04418	0.01098	4.02	<.0001
CO_Term	1	0.17796	0.02229	7.98	<.0001
NO_Term	1	0.08789	0.01374	6.39	<.0001
NO_Term2	1	0.01483	0.00582	2.55	0.0110
MY_Term	1	-0.12753	0.01029	-12.40	<.0001
MY_Term2	1	-0.00681	0.00262	-2.60	0.0096
TRK	1	0.37580	0.04756	7.90	<.0001

1990+ MY Vehicles
Humidity Corrected NOx Values

The REG Procedure
Model: MODEL3
Dependent Variable: ln_NOx

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	302.70933	50.45155	224.16	<.0001
Error	623	140.21962	0.22507		
Corrected Total	629	442.92894			

Root MSE	0.47442	R-Square	0.6834
Dependent Mean	-1.00840	Adj R-Sq	0.6804
Coeff Var	-47.04652		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > t
Intercept	1	-6.51660	1.04669	-6.23	<.0001
NO_Term	1	0.25586	0.01166	21.94	<.0001
NO_Term2	1	0.04326	0.00501	8.63	<.0001
Wt_Term	1	0.65599	0.12926	5.08	<.0001
MY_Term	1	-0.09092	0.00810	-11.22	<.0001
MY_Term2	1	-0.00998	0.00228	-4.38	<.0001
TRK	1	0.24958	0.05150	4.85	<.0001

Appendix 2B

EMFAC2002 Calendar Year 1999 and Calendar Year 2002 Emission Factors and Ratios Used to Forecast the "1999 Before ASM" Roadside Data to a Calendar Year 2002 Basis

MYR	CY 1999 Emission Factors (g/mi)			CY 2002 Emission Factors (g/mi)			CY2002/CY1999 Ratios		
	HC	CO	NOX	HC	CO	NOX	HC	CO	NOX
1974	6.7725	56.4781	2.6857	6.9646	57.1811	2.5865	1.028	1.012	0.963
1975	3.2843	33.8806	2.6708	3.4767	34.8401	2.6071	1.059	1.028	0.976
1976	3.2821	34.0682	2.6568	3.4712	35.0540	2.5936	1.058	1.029	0.976
1977	2.7866	35.8303	1.9040	2.8884	37.2258	1.8811	1.037	1.039	0.988
1978	2.7875	36.2720	1.9238	2.9049	37.5453	1.9027	1.042	1.035	0.989
1979	2.6688	34.8167	1.9423	2.8015	36.0398	1.9169	1.050	1.035	0.987
1980	2.0780	31.6443	1.7858	2.0816	31.7817	1.7895	1.002	1.004	1.002
1981	2.2995	27.8516	1.6037	2.4027	28.1250	1.6166	1.045	1.010	1.008
1982	2.2649	28.1308	1.6089	2.3795	28.5167	1.6253	1.051	1.014	1.010
1983	2.1904	27.9615	1.5791	2.3051	28.4482	1.5983	1.052	1.017	1.012
1984	2.0936	27.0603	1.5504	2.2340	27.5887	1.5739	1.067	1.020	1.015
1985	1.4737	19.8008	1.3558	1.5253	20.7302	1.4121	1.035	1.047	1.042
1986	1.4072	16.4931	1.3024	1.4741	17.4210	1.3842	1.048	1.056	1.063
1987	1.3686	15.6993	1.2651	1.4450	16.7384	1.3547	1.056	1.066	1.071
1988	1.3318	14.9322	1.2255	1.4191	16.1538	1.3245	1.066	1.082	1.081
1989	1.2744	13.8375	0.9742	1.3884	15.1668	1.0612	1.089	1.096	1.089
1990	1.1984	13.1702	0.7775	1.3626	14.6061	0.8576	1.137	1.109	1.103
1991	1.1013	12.6712	0.7424	1.3327	14.1666	0.8345	1.210	1.118	1.124
1992	1.0034	12.1304	0.7026	1.2894	13.6857	0.8082	1.285	1.128	1.150
1993	0.7907	9.3548	0.6333	1.0506	10.7411	0.7454	1.329	1.148	1.177
1994	0.5243	5.7396	0.5181	0.7295	6.8987	0.6254	1.391	1.202	1.207
1995	0.3943	4.2177	0.4630	0.5791	5.4100	0.5773	1.469	1.283	1.247
1996	0.2269	2.1779	0.3688	0.3326	3.2523	0.4591	1.466	1.493	1.245
1997	0.1786	1.9196	0.2954	0.2714	2.9028	0.3724	1.520	1.512	1.261
1998	0.1194	1.5484	0.2129	0.1745	2.2130	0.2717	1.461	1.429	1.276

